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ART. I.—*Contributions to Meteorology: being results derived from an examination of the observations of the United States Signal Service, and from other sources;* by ELIAS LOOMIS, Professor of Natural Philosophy in Yale College. Fourteenth paper, with Plates I, II, III.

[Read before the National Academy of Sciences, New York, Nov. 18, 1880.]

THE object of this paper is to investigate the course and velocity of storm centers in Tropical regions and also in the middle latitudes, and hence to deduce the causes which control their movements.

Course and velocity of storm centers in Tropical regions.

In my fifth paper (this Journal, vol. xii, p. 15,) I gave a table showing the course of those hurricanes which have originated near the West India Islands. That table was prepared in pursuance of a plan to determine the course of storms under the greatest variety of circumstances; and since the table exhibited but a small part of the information which I desired to obtain, I did not attempt to develop the conclusions which it naturally suggested. Soon after the publication of that paper, I prepared another table showing the course of hurricanes in the India and China Seas; but as this did not furnish all the information that I desired, I have hitherto withheld it from publication in expectation of more complete information. The system of International Meteorological observations has in part supplied the desired information, so that I propose now to consider the results already attained.

I have compared all the storm tracks delineated on the maps of the Monthly Weather Review, and also those delineated on the International charts. I first examined the storms which have prevailed in the neighborhood of the American continent, confining myself to those cases in which the storm center (during at least a part of its course) was south of the parallel of 30° latitude. I have divided these storms into three classes; I, those whose course was for some days towards the west; II, those whose course was towards some point between the south and east; III, those whose course was towards some point between the north and east.

The following table shows the leading particulars respecting the first of these classes. Column 1st shows the number of reference; column 2d shows the dates of beginning and end of the observed movement as long as the course continued westerly; column 3d shows the latitude at the beginning and end of this portion of the path; column 4th shows the longitude at the beginning and end of this portion of the path; column 5th shows the prevalent direction of the path while moving westerly; column 6th shows the average velocity of progress of the storm center (in miles per hour) while the course continued westerly; column 7th gives a brief indication of the subsequent course of each storm. On plate I these tracks are delineated and are designated by the same numbers as in the table.

American storms advancing Westerly.

No.	Date.	Latitude. beg.	Latitude. end.	Longitude. beg.	Longitude. end.	Course.	Vel., miles.	Subsequent course.
1	1873. June 1.1– 2.3	24°	32°	80°	86°	N.N.W.	12·5	Became extinct.
2	Oct. 2 – 4.2	22	24	82	86	N.W.	9·5	Moved N.E.
3	1874. Feb. 7 – 8.1	24	27	82	83	N.N.W.	15·4	Moved N.E.
4	July 2.3– 4.2	27	29	87	98	W.N.W.	13·1	Became extinct.
5	Sept. 4.3– 5.3	25	32	65	70	N.N.W.	22·5	Moved N.E.
6	1875. Sept. 8.3–17.1	14	29	59	96	W.N.W.	13·2	Moved N.E.
7	1876. Sept. 15 –18.1	21	43	69	80	N.N.W.	25·9	Moved E.
8	1877. Sept. 22.2–30.3	12	26	65	88	W.N.W.	11·1	Moved N.E.
9	1878. Aug. 12 –18	14	21	75	97	W.N.W.	14·4	Unknown.
10	Sept. 1 – 8	11	28	59	81	W.N.W.	9·3	Moved N.
11	Sept. 12 –18	14	29	47	60	N.W.	9·6	Moved N.E.
12	Sept. 24 –30	14	28	70	73	N.N.W.	5·3	Moved N.E.
13	Sept. 29 –34	22	30	58	70	N.W.	9·1	Moved N.E.
14	Oct. 9 –13	15	26	40	52	N.W.	7·2	Moved N.E.
15	Oct. 13 –18	17	30	36	55	N.W.	13·2	Moved N.
16	Nov. 25 –30	15	17	52	73	West.	11·7	Unknown.
17	1879. Aug. 13 –17	18	30	60	77	N.W.	8·2	Moved N.E.
18	Aug. 15 –16	14	14	43	51	West.	?	Unknown.
19	Aug. 20 –23	16	29	87	94	N.W.	8·2	Moved E.
20	Oct. 3 – 7	15	31	78	90	N.W.	8·1	Became extinct.
21	Oct. 10 –17	14	43	70	90	N.W.	11·1	Moved E.
22	1880. Aug. 6 –14.2	12	32	77	103	W.N.W.	12·9	Disappeared.
23	Aug. 15 –19	13	20	62	78	W.N.W.	12·0	Moved N.E.
24	Aug. 24 –31	26	33	60	89	W.N.W.	10·0	Disappeared.

The general results of this table correspond very closely with those deduced from the table in my 5th paper. The lowest latitude of any storm center shown in this table is 10°·6 N. The lowest latitude shown in my 5th paper was 10°·3 N. The average velócity of these storms while moving westerly was 11·9 English statute miles per hour; the average velocity of the storms mentioned in my 5th paper while moving westerly was 17·4 miles per hour. In nine of these cases the course of the storm became due north before reaching the parallel of 30°.

Storm No. 18 apparently moved directly west; and storms Nos. 9 and 16 apparently moved for a day or two a little south of west. The table in my 5th paper shows 31 cases in which the course of storms was towards the north of west, and only two cases in which the course was south of west, viz: one case in which the course was two degrees south of west, and the other eleven degrees south of west. From the two tables we perceive that the cases in which tropical storms move in a direction north of west are fifteen times as frequent as the cases in which they move in a direction south of west, and in none of the cases here reported was the southerly motion very decided. Since in the middle latitudes the average progress of storm centers corresponds pretty nearly with the average direction of the wind, it might have been inferred that within the region of the northeast trade winds the average progress of storms should be towards the southwest.

In order to determine whether, during the period here considered, there may not possibly have been other storms which moved in a direction south of west, I have made a careful comparison of the International Observations. Five-sixths of all the storms enumerated in the table on page 2, occurred in the months of August, September and October. I therefore selected these three months for special comparison. For the years 1876, 7, 8 and 9 the barometric curves were drawn for these months for all the stations reported in the International Bulletin between the equator and lat. 26° N.

An examination of these curves shows that at all of these stations the fluctuations of the barometer are very small, particularly for the stations nearest to the equator. At Paramaribo, lat. 5° 45′ N. the entire range of the barometer for these twelve months was only 0·20 inch, and there was no oscillation which can be identified with an oscillation at either of the other stations. At Bridgetown, lat. 13° 4′ N., the entire range of the barometer for these twelve months was 0·23 inch. Two or three of the barometric oscillations at this station can probably be identified with oscillations at some of the other stations. The track of storm No. 9 can apparently be traced back to Bridgetown on the 10th of Aug., 1878. At Fort de France, lat. 14° 40′ N.,

the entire range of the barometer for these twelve months was 0·42 inch, and six or seven of the barometric oscillations at this station can probably be identified with oscillations at some of the other stations.

Besides the areas of low barometer enumerated in the table on page 2, there are but few others during this period which can be traced with confidence from one station to another. In 1876, the number of stations of observation in the tropical regions was small, and the storm of Sept. 15–18 is the only one which can be satisfactorily traced from these observations.

In 1877, the center of storm No. 8 passed at a considerable distance from all of the reporting stations, and is only obscurely indicated by the published observations. On the 26th of August, a small but well-marked barometric depression occurred almost simultaneously at all of the stations from Fort de France to Havana. On the 17th and 18th of October, there was a noticeable fall of the barometer, which apparently advanced from San Juan de Porto Rico to Havana.

In 1878, from Sept. 15th to 16th, a small barometric depression traveled from Bridgetown to Santiago de Cuba. From the 2d to the 3d of October, a small barometric depression traveled from Fort de France to Nassau. On the 21st of October, there was a decided barometric depression at Vera Cruz and Havana, which advanced northerly along the coast of the United States, and was marked by great violence.

In 1879, from the 16th to the 18th of August, a small barometric depression traveled from Bridgetown to San Juan de Porto Rico. This was perhaps a continuation of No. 18, of the table on page 2, and if so, it shows that this storm veered a little to the north of west, like most of the storms of this region. On the 28th of August, a small barometric depression appeared almost simultaneously at all the stations from Navassa to Tlacotalpam, on the coast of Mexico. This depression apparently advanced northward, but the published observations are not sufficient to enable us to trace its course satisfactorily.

This examination has disclosed a few barometric depressions in addition to those enumerated in the table on page 2, but their courses were generally towards the north of west. We therefore seem authorized to conclude that nearly all the areas of low barometer which occur within the tropics and advance westward, in the neighborhood of the West India Islands, instead of following the ordinary course of the Trade Winds, advance in a direction somewhat north of west.

American storms advancing in a Southeasterly direction.

During the colder months of the year, storms while crossing the United States frequently advance, during a portion of their

course, in a direction from northwest to southeast. This direction is not confined to any particular section of the country, but occurs most frequently in the region between the Rocky Mountains and the Mississippi River. This course is seldom maintained as far south as the parallel of 30°, and after reaching its most southerly point, the storm frequently changes its course towards the northeast. The following table shows those cases in which storms have advanced towards the southeast as far as the parallel of 28°. The arrangement is similar to that of the preceding table. The first six columns describe each storm as long as its course continued southeasterly; the last column gives some indication of the subsequent course of each storm. The tracks of these storms are all delineated on Plate II, and are designated by the same numbers as in the table.

American storms advancing Southeasterly.

No.	Date.	Latitude. beg.	Latitude. end.	Longitude. beg.	Longitude. end.	Course.	Vel., miles.	Subsequent course.
1	1874. Feb. 17.2–18.2	33°	27°	86°	79°	S.E.	21·8	Unknown.
2	April 15.3–16.3	41	26	101	89	S.E.	21·1	Unknown.
3	1875. Jan. 15.1–16.2	44	27	106	91	S.E.	27·1	Unknown.
4	1876. Feb. 3 – 4.1	33	28	98	80	S.E.	28·4	Unknown.
5	March 6.2–12.1	47	27	127	89	S.E.	15·7	Unknown.
6	May 6.3– 7.3	33	27	100	93	S.E.	25·0	Unknown.
7	1877. Jan. 4.2– 5.3	46	28	100	90	S.S.E.	40·4	N.E.
8	Mar. 21.2–24.1	42	28	100	95	S.S.E.	22·5	N.E.
9	Dec. 19 –20	44	28	102	98	S.E.	10·0	N.
10	Dec. 22 –27.2	47	27	102	95	S.E.	29·7	N.E.
11	1878. Feb. 1.1– 2.3	33	26	96	84	S.E.	18·3	N.E.
12	Aug. 20.2–24.2	38	22	83	81	S.S.E.	15·1	Became extinct.
13	Nov. 16.2–17.2	28	24	102	93	S.S.E.	24·0	N.E.
14	1879. Jan. 6.3– 7.3	38	27	110	98	S.E.	39·2	N.E.
15	Jan. 8.3–11.1	49	27	119	98	S.E.	30·4	N.E.
16	May 4.1– 6.1	34	24	101	96	S.S.E.	16·1	Became extinct.

We see from this table that the average velocity of these storms while pursuing their course towards the southeast, was twenty-four miles per hour, which differs but little from the average velocity of storms in other parts of the United States. The lowest latitude attained by any of these storms was $22\frac{1}{2}$ degrees; and in only three cases did the low center reach the parallel of 25 degrees. In eight cases the storm center, after completing its course towards the southeast, changed its course and proceeded towards the north or northeast. In two of the remaining cases the intensity of the storm declined in advancing southward, and they apparently became extinct soon after the dates given in the table. The same was probably true in the six remaining cases, but the observations are not sufficient to establish this with certainty.

Storm No. 12 was quite peculiar, having pursued a path almost directly opposite to that of ordinary storms. During the afternoon of Aug. 20th, 1878, there was an area of low pressure (29·75) over West Virginia, being part of a greater depression whose center was over Newfoundland, and there was a slight tendency to the formation of an independent system of circulating winds. Owing to a slight increase of pressure on the north side, this low area was crowded southward, and in the afternoon of Aug. 21st assumed the character of an independent low area (29·78) with a feeble system of circulating winds. At 7.35 A. M. Aug. 22d, this low center had been crowded south to lat. 30°, the greatest observed depression being now 29·88. After this the pressure increased, and the low center could not be distinctly traced. This example appears to illustrate the general character of areas of low pressure, and shows that their progressive movement is not due to a simple drifting of the atmosphere, but rather to a diminution of pressure on one side of the low area and an increase of pressure on the other side. In the present case, there was scarcely any appreciable diminution of pressure on the south side, and only a slight increase of pressure on the north side.

American storms advancing Northerly and Easterly.

The storms which cross the United States north of the parallel of 38 degrees, generally pursue a course a little to the north of east; while those which come from the region south of lat. 38 degrees generally pursue a course nearly northeast, especially in the neighborhood of the Atlantic coast. During the summer months few storm-centers travel south of the parallel of 38°, and during this period the average course of storms is almost exactly towards the east.

The following table shows those cases in which storms have traveled northward and eastward, and came from a point as far south as lat. 26°. The arrangement of the table is similar to that of the preceding. Columns 3 and 4 show the position of the storm-center at the beginning and end of the northeasterly motion, as far as is indicated by the observations; column 7th shows the lowest pressure reported, and column 8th gives a brief indication of the previous course of the storm. On Plate III these tracks are delineated and are designated by the same numbers as in the table.

We see from this table that storms of this class occur most frequently in the autumn, and least frequently in summer. One of these storms began near lat. 15°; two began near lat. 20°; and seventeen of them began south of lat. 24°.

American storms advancing Northerly and Easterly.

No.	Date.	Latit'e. beg. end	Long. beg. end	Course.	Vel., miles.	Lowest Barom.	Previous course.
		° °	° °				
1	1872. Nov. 6.1– 7.3	26–47	95–65	E.N.E.	60·4	29·71	Unknown.
2	Nov. 7.3– 9.3	25–30	95–78	E.N.E.	21·1	29·74	Unknown.
3	Dec. 9.2–13.3	26–47	101–57	N.E.	28·6	29·86	Unknown.
4	Dec. 23.2–27.2	25–44	95–58	N.E.	29·8	29·17	Unknown.
5	1873. Feb. 19.1–22.1	21–45	98–64	N.E.	35·1	29·17	Unknown.
6	May 4.1–10.1	24–43	98–81	N.E.	15·8	29·57	Unknown.
7	Sept. 18.1–20.1	24–34	92–74	N.E.	24·3	29·57	Unknown.
8	Sept. 22.3–24.1	25–36	86–72	N.E.	28·5	29·78	Unknown.
9	Oct. 5.1– 8.2	25–43	87–62	N.E.	32·9	29·02	Towards N.W.
10	Dec. 24.2–27.1	24–43	88–62	N.E.	30·4	29·37	Unknown.
11	1874. Jan. 5.2– 9.1	25–49	87–68	N.N.E.	18·0	29·42	Unknown.
12	Feb. 7.2–11.1	25–46	82–58	N.N.E.	25·0	28·95	Towards N.W.
13	April 17.3–24.1	24–46	94–59	N.& N.E.	29·7	29·36	Unknown.
14	Sept. 2.3–10.2	22–50	99–89	North.	21·5	29·47	Unknown.
15	Sept. 27.1–30.2	25–50	87–66	N.N.E.	26·0	28·94	Unknown.
16	Dec. 18.2–21.1	25–39	96–62	N.E.	34·6	29·33	Unknown.
17	1875. Nov. 6.1– 7.3	25–31	98–78	E.N.E.	32·9	29·82	Unknown.
18	1876. Oct. 19.1–21.1	21–32	82–72	N.N.E.	19·5	29·51	Not traceable.
19	1877. Sept. 16.1–21.3	25–31	96–76	E.N.E.	10·7	29·40	Unknown.
20	1878. Jan. 6.1–12.2	24–46	100–56	N.E.	26·4	28·85	Not traceable.
21	Feb. 26.2–28.1	24–30	92–71	E.N.E.	31·1	29·71	Came from N.W.
22	Mar. 17.1–17.2	23–25	85–78	E.N.E.	?	29·79	Not traceable.
23	Mar. 19.3–22.3	25–27	95–78	East.	15·0	29·71	Came from W.
24	July 2.1– 2.3	25–27	85–78	E.N.E.	22·9	29·77	Not traceable.
25	Sept. 24 –33	15–32	76–61	N.& N.E.	10·1	29·70	Not traceable.
26	Oct. 21.1–24.2	20–38	81–57	N.& E.	27·5	28·83	Not traceable.
27	Nov. 13.3–20.1	22–44	97–57	E.& N.E.	24·5	29·83	Not traceable.
28	Nov. 17.2–21.1	24–47	93–57	N.E.	40·3	29·47	Came from N.W.
29	1879. Nov. 19.1–20.3	23–49	74–60	N.N.E.	48·8	29·00	Not traceable.
30	1880. Jan. 24 –28.1	21–36	86–75	N.	14·3	29·68	Not traceable.
31	March 7.3– 9.2	26–32	99–74	E.N.E.	38·0	29·86	Not traceable.
32	May 3.1– 6.2	26–47	93–59	N.E.	23·8	29·79	Unknown.
33	Aug. 19 –20	20–27	78–74	N.N.E.	12·4	29·86	Towards N.W.

Three of these storms had been traveling towards the northwest, previous to the dates given in the table, and two of them came from the northwest; but in the other cases the barometric depression was too small to allow us to trace their course previous to the dates here given. For most of the cases in the last half of the table this is clearly shown by the International Observations, and we may therefore infer it to be true in the other cases. As long as these storms continued south of lat. 30°, the barometric depression was generally small, but it increased as the storm advanced northward. In fifteen cases the barometer fell below 29·5 inches, and in four cases it fell below 29·0 inches. The average velocity of progress of these storm-centers while advancing northward and eastward was 26·9 miles per hour. From a comparison of these three tables we perceive that the American storms which originate between the equator and lat. 20° N. generally travel towards a point

between north and west, but occasionally they advance almost exactly northward.

Course of hurricanes originating near the Bay of Bengal, China Sea, etc.

The following table contains various particulars respecting those hurricanes in Southern Asia and its vicinity, whose paths have been best determined. It includes all those which were most carefully investigated by Henry Piddington, together with those which have been since investigated by Blanford, Elliott and others. Column 1st gives the number of reference; column 2d shows the date of commencement, so far as indicated by the published observations; column 3d shows the latitude of the storm's center when it first became violent; column 4th shows the average course of the storm while advancing westward; column 5th shows the velocity of progress in English statute miles per hour while moving westward; column 6th shows the latitude at which the course of the storm became due north; column 7th shows the velocity while moving north; column 8th shows the average course of the storm after turning eastward; column 9th shows the hourly velocity of progress while moving eastward; column 10th shows whether rain was mentioned as accompanying the storm, and whether the rain-fall was violent or not; column 11th indicates the name of the person by whom the phenomena of the storm were investigated. (P.) stands for Henry Piddington; (B.) for Henry F. Blanford; (E.) for J. Elliott; (R.) for William C. Redfield; (F.) for J. Floyd; (M.) for Matthew F. Maury; (L.) for G. von Liebig; (G.) for Colonel J. E. Gastrell and Henry F. Blanford; and (W.) for W. G. Willson. Column 12th shows where the record of the investigation may be found. J. A. S. stands for Journal of the Asiatic Society of Bengal; J. S. for the American Journal of Science; S. D. for Maury's Sailing Directions; the other references are to special reports made by the investigators to the Government of Bengal.

It will be seen that 52 per cent of these cases occurred in the months of September, October and November, and 43 per cent occurred in the months of April, May and June, leaving only 5 per cent of the cases for the six remaining months of the year. Of the West India hurricanes reported in my fifth paper, 88 per cent occurred in the months of August, September and October, leaving only 12 per cent for the remaining nine months of the year: that is, the Asiatic hurricanes occur in the spring almost as frequently as in the autumn; but the American hurricanes are almost exclusively confined to the period near the autumnal equinox.

Course of Hurricanes originating near the China Sea, Bay of Bengal, etc.

No.	Date of Commencement.	Latitude of Origin.	Course while moving Westward.	Velocity in miles per hour.	Latitude when moving North.	Velocity moving North.	Course while moving Eastward.	Velocity moving Eastward.	Rain-fall.	Investigator.	Where recorded.
1	1803. Sept. 21	16·0	W. 15 N.	9·1					Heavy	P.	J. A. S., v. 11
2	1810. Sept. 28	18·1	W. 12 S.	7·3					Heavy	P.	J. A. S., v. 11
3	1835. Aug. 5	20·5	W. 18 N.	17·0					Heavy	R.	J. S., v. 35
4	1838. April 8	22·6					S. 37 E.	5·0	Hail	F.	J. A. S., v. 7
5	1839. June 3	20·0	W. 13 S.	3·9					Violent	P.	J. A. S., v. 8
6	Sept. 20	22·0	W. 52 N.	9·5					Violent	P.	J. A. S., v. 9
7	Nov. 12	13·3	W. 23 N.	6·2					Heavy	P.	J. A. S., v. 9
8	1840. April 27	11·6	W. 54 N.	9·8					Violent	P.	J. A. S., v. 9
9	Sept. 22	15·6	W. 83 N.	10·0					Violent	P.	J. A. S., v. 10
10	1841. May 15	10·0	W. 25 N.	14·7					Heavy	P.	J. A. S., v. 11
11	1842. June 2	20·5	W. 69 N.	4·8					Violent	P.	J. A. S., v. 11
12	Oct. 1	17·7	W. 31 N.	7·5	24·3	4·6			Violent	P.	J. A. S., v. 12
13	Oct. 22	12·0	West.	12·1					Violent	P.	J. A. S., v. 12
14	1843. May 20	8·8	W. 38 N.	12·1					Heavy	P.	J. A. S., v. 13
15	Nov. 28	6·1	W. 40 N.	4·6					Rain	P.	J. A. S., v. 14
16	1844. Nov. 9	11·1	W. 16 N.	3·4					Heavy	P.	J. A. S., v. 14
17	1845. Oct. 7	17·1	W. 19 N.	13·5					Rain	P.	J. A. S., v. 18
18	Nov. 29	6·7	W. 12 N.	6·0					Violent	P.	J. A. S., v. 14
19	1847. April 16	7·9	W. 86 N.	9·4					Violent	P.	J. A. S., v. 17
20	Nov. 18	17·0	W. 49 N.	6·2	18·5	5·8	N. 53 E.	5·0	Rain	P.	J. A. S., v. 18
21	1848. Oct. 12	17·8	W. 50 N.	4·8					Rain	P.	J. A. S., v. 18
22	1850. April 23	8·7	W. 50 N.	8·1	18·0	9·1			Violent	P.	J. A. S.. v. 20
23	Nov. 17	12·2	W. 70 N.	6·0					Heavy	P.	J. A. S., v. 23
24	1851. May 2	10·6	W. 54 N.	3·6					Violent	P.	J. A. S., v. 21
25	Oct. 21	17·6			17·6	10·9	N. 42 E.	5·7	Rain	P.	J. A. S., v. 23
26	1852. May 12	15·7			20·0	10·1			Rain	P.	J. A. S., v. 24
27	1854. April 22	13·2					N. 39 E.	9·8	Heavy	P.	J. A. S., v. 27
28	1856. Dec. 7	10·0	W. 24 N.	11·7					Violent	M.	S. D., v. 1
29	1858. April 9	14·2					N. 39 E.	12·1	Violent	L.	J. A. S., v. 27
30	1864. Oct. 3	16·0	W. 56 N.	9·2	21·3	12·0	N. 29 E.	15·0	Violent	G.	Report.
31	1869. May 13	16·0	W. 44 N.	7·6	20·5	14·0	N. 25 E.	17·0	Rain	B.	Report.
32	June 5	16 4	W. 83 N.	4·0	24·0	9·5	N. 39 E.	11·0	Violent	B.	Report.
33	Oct. 7	20·5	W. 34 N.	12·5					Violent	B.	Report.
34	1870. Nov. 4	16·5	W. 11 N.	12·0					Violent	B.	Report.
35	1872. April 28	7·5	W. 50 N.	5·0					Heavy	B.	Report.
36	June 28	20·5	W. 21 N.	7·1					Violent	B.	Report.
37	Sept. 19	21·0			23 0	12·7	N. 43 E.	13·7	Violent	B.	Report.
38	1874. May 3	9·0	W. 39 N.	7·0					Violent	B.	Report.
39	Oct. 13	16·6	W. 60 N.	6·9	22·1	8·3	N. 40 E.	9·4	Violent	W.	Report.
40	1876. Oct. 6	14·4	W. 25 N.	7·5	17·6	6·0	N. 16 E.	8·0	Heavy	E.	Report.
41	Oct. 27	11·0			14·0	10·0	N. 17 E.	20·0	Violent	E.	Report.
42	1877. May 14	9·3	W. 63 N.	5·0	15·0	7·9	N. 45 E.	10·4	Violent	E.	Report.

The lowest latitude of any storm-path here recorded is 6·1°, and there are fourteen cases as low as 12°. The lowest latitude of any of the West India hurricanes is 10°·3, and there are only three cases as low as 12°.

Hard gales and violent squalls of wind do, however, sometimes occur directly under the equator. This is shown by various logs quoted in Piddington's Memoirs. The following is an

example from the log-book of the Winifred, quoted in Piddington's 11th Memoir, pages 30 to 40:

1843, Nov.	26,	lat.	9°	40′ N.	Dark and threatening—strong, heavy squalls.
Nov.	27,	"	7	4 N.	Sudden and dangerous gusts and violent squalls.
Nov.	28,	"	4	27 N.	Heavy rain and most terrific squalls.
Nov.	29,	"	1	20 N.	Succession of dangerous squalls.
Nov.	30,	"	1	1 S.	Dismal weather and violent squalls.
Dec.	1,	"	3	15 S.	Dark, gloomy weather and violent squalls.

The following is from the log-book of the Fyzul Curreem, for the same period:

1843, Nov.	27,	lat.	5°	11′ N.	Heavy squalls, N.N.W.
Nov.	28,	"	2	6 N.	Fresh gale, west.
Nov.	29,	"	0	54 S.	Gale from west, increasing steadily to midnight.
Nov.	30,	"	3	50 S.	Steady at west.
Dec.	1,	"	5	39 S.	Strong sea from W.S.W.
Dec.	2,	"	6	41 S.	Heavy head sea.

The courses of these storms while moving westward, range from 13 degrees south of west to 86 degrees north of west. In two cases the course was reported to be south of west, and in one case it was exactly west, which result accords very closely with that before found for West India hurricanes. The average velocity of progress of these storms while advancing westward was 8·1 English statute miles per hour, which is less than half the average velocity of West India hurricanes.

The average latitude of the storm-centers when the course became due north was 19·8, and the latitudes range from 14° to 24°·3, which is ten degrees more southerly than the latitude before found for the West India hurricanes. The average velocity of progress of these storms when advancing northward was 9·3 miles per hour.

The average course of these storms after turning eastward, was 35° east of north, and their velocity of progress was 9·8 miles, which is scarcely half of the velocity found for West India hurricanes.

Column 10th shows that rain accompanied every one of these storms, and generally the rain-fall was excessively great. These observations were generally made from vessels on the ocean, and the amount of the rain-fall could not be measured, but the rain was generally characterized by the strongest terms which the English language furnishes, such as: very heavy rain--constant heavy rain—ceaseless rain—excessively heavy rain—incessant heavy rain—sheets of rain—deluge of rain—rain poured down in torrents—dense, thick, impenetrable rain—rain with a vengeance—rain and very large hail—rain and sleet—hard sleet—torrents of rain and sleet, etc.

When a storm-center passed overland, where a rain-gauge was observed, the measurements showed that the preceding terms were no exaggeration. The following table shows the amount of rain-fall in twenty-four hours at certain stations:

Rain-fall in Tropical Cyclones.

Date.	Place.	Lat.	Long.	Rain, inches	Authority.
1839. June 4	Dacca	23°·7	90°·5	6·00	Piddington, 1st Memoir, p. 37
1842. June 3	Calcutta	22·5	88·3	5·17	7th Memoir, p. 35
June 3	Kissenuggur	23·4	88·4	9·00	7th Memoir, p. 42
Oct. 3	Pooree	19·8	85·9	5·10	9th Memoir, p. 27
1843. May 23	Cannanore	11·9	93.2	5·95	10th Memoir, p. 32
May 23	Madras	13·1	80·3	10·50	10th Memoir, p. 20
May 23	Hyderabad	25·3	68·4	9·00	10th Memoir, p. 29
1851. May 5	Madras	13·1	80·3	11·44	21st Memoir, p. 17
1864. Oct. 6	Contai	21·8	87·8	10·00	Rep. of Gastrell & Blanford, p. 82
Oct. 6	Bograh	24·8	89·4	7·10	p. 82
Oct. 6	Goalparah	26·2	90·7	60·00	p. 82
Oct. 6	Moisgunj	23·4	88·5	7·50	p. 82
1874. May 4	Madras	13·1	80·3	7·10	Willson's Report, p. 127
Oct. 15	False Point	20·3	86·8	6·30	p. 9
Oct. 15	Jellasore	21·5	86·9	5·82	p. 9
Oct. 15	Midnapore	22·4	87·2	10·27	p. 8
Oct. 16	Burdwan	23·2	87·9	7·43	p. 8
Oct. 16	Lalgolla	24·5	88·3	16·30	p. 8
Oct. 16	Jungipore	24·5	87·8	8·00	p. 8
Oct 16	Bood Bood	23·	88·	8·40	p. 8
Oct. 17	Rungpore	25 9	89·3	6·97	p. 9
1876. Oct. 7	Vizagapatam	17·7	83·4	5·60	Elliott's Report, p. 48
Oct. 8	Vizagapatam	17·7	83·4	12·60	p. 48
Nov. 1	Noakholly	22·8	91·0	5·12	p. 153
Nov. 1	Putuakhally	22·3	90·4	5·85	p. 153
1877 May 18	Madras	13·1	80·3	13·01	p. 42
May 20	Gya	24·6	85·1	5·06	p. 75
May 20	Nowada	23·9	88·4	8·00	p. 75
May 20	Aurungabad	19·9	75·3	8·68	p. 75
May 20	Rajmahal	25·0	87·7	5·20	p. 75
May 20	Raigunge	25·	88·	5·71	p. 75
May 20	Jawai	25·	91·	9·70	p. 75
May 21	Barrh	25·5	85·7	6·43	p. 77
May 21	Chanchal	25·0	88·2	6·14	p. 77
May 21	Rungpore	25·9	89·3	11·16	p. 77
May 21	Kurigram	25·	89·	5·70	p. 77
May 21	Bogdogra	25·	89·	12·19	p. 77
May 21	Julpigoree	26·5	88·7	5·53	p. 77
May 21	Boda	26·	89·	8·52	p. 77
May 21	Cooch Behar	26·3	89·5	9·77	p. 77
May 21	Dhubri	26·0	90·0	5·60	p. 77
May 21	Jawai	25·	91·	14·20	p. 77

From this table we see that these hurricanes were accompanied by an amount of rain such as seldom occurs, even within the tropics, and we seem authorized to conclude that excessive rain invariably accompanies the most violent hurricanes. This conclusion accords with that deduced from the investigation of the West India hurricanes.

I next examined all the maps of the International Observations for additional materials, showing the course of storms in Southern Asia and the adjacent oceans. The following are the most important cases which I have found:

Asiatic storms moving Westerly.

No.	Date.	Latitude. beg.	Latitude. end.	Longitude. beg.	Longitude. end.	Course.	Vel., miles.	Subsequent course.
1	1878. Sept. 15–19	16°	29°	134°	124°	N.W.	10·8	Moved N.E.
2	Oct. 7– 9	19–	19	122–	112	West	14·3	Unknown.
3	Nov. 17–21	12–	15	95–	82	West	6·6	Disappeared.
4	Nov. 29–38	10–	18	97–	83	W.&N.W.	5·8	Disappeared.
5	1879. May 17–26	14–	35	85–	75	S.&W.&N.	12·4	Disappeared.
6	May 30–32	20–	22	88	90	West	7·2	Disappeared.

Asiatic storms moving Southeasterly.

7	1877. Dec. 27–30	27–	20	65–	80	E.S.E.	18·1	Moved N.E.
8	1878. Feb. 6–12	39–	22	60–	92	E.S.E.	16·7	Disappeared.
9	May 3– 8	33–	17	77–	79	South	10·0	Disappeared.
10	June 2– 7	66–	26	110–	112	South	15·4	Moved N.E.

Asiatic storms moving Northeasterly.

11	1879. Mar. 2– 6	6–	34	118–	152	N.E.	21·8	Unknown.
12	Mar. 15–22	10–	40	113–	157	N.E.	15·4	Unknown.

In several of these cases the depression of the barometer, so far as reported, was not very great, and the storms do not appear to have been of remarkable violence, nevertheless the results here found accord reasonably well with those before found, except that the velocities while the storms were moving easterly, are greater than the average of those shown in the table on page 9.

On comparing all these tables it is remarkable that but few cases have been found in which a storm-center has advanced towards any point between west and south. Including the table in my fifth paper, we have found 98 cases of tropical storms which advanced westerly, and of these only five moved towards any point between south and west. The first of these advanced in a direction about two degrees south of west; the second advanced eleven degrees south of west; the third advanced twelve degrees south of west; the fourth advanced thirteen degrees south of west; and the fifth, starting from lat. 30°, advanced for three days in a direction nearly south, then one day nearly west, and subsequently towards the northwest.

I next endeavored to ascertain what was the prevalent direction of the wind which preceded each of these tropical storms, and also the prevalent wind which succeeded the low center, and how these two winds generally compared in respect of force. It is impossible to make a satisfactory comparison from the observations in the International Bulletin, on account of the small number of stations, and because the observations are reported only once a day. The following tables show the direction and force of the wind in the case of five of the low areas

enumerated on page 2, for the stations nearest the center of low pressure. The numbers without brackets show the velocity of the wind in miles per hour; the numbers in brackets show the force of the wind estimated in units of Beaufort's scale (1 to 10). In each line the direction and force for one day are printed in large type, to indicate the day when the barometer at that station was lowest.

1876, *September.*

	14th.	15th.	16th.	17th.	18th.	19th.
Kingston	Calm	**S.E.5**	S.E.8	S.E.8	Calm	Calm
Nassau	N.E.(3)	N.E.(8)	**S.E.(6)**	S.(3)	N.E.0	N.E.(5)

1878, *August.*

	10th.	11th.	12th.	13th.	14th.	15th.
San Juan	S.E.2	**E.12**	S.E.4	S.E.8	S.E.0	S.E.2
Navassa	S.E.12	N.E.10	**N.19**	S.E.29	E.17	E.17
Kingston	Calm	Calm	Calm	**S.E.10**	S.E.20	Calm
Nassau	S.E.(1)	N.E.(2)	N.E.(2)	S.E.(1)	**S.E.2**	S.E.(2)
Havanna	E.4	E.S.E.4	E.S.E.3	E.N.E.4	**E.9**	S.E.16

1878, *September.*

	3d.	4th.	5th.	6th.	7th.	8th.
Navassa	S.19	N.20	**S.22**	S.E.20	E.14	E.15
Santiago de Cuba	N.E.7	N.6	**S.E.(6)**	S.E.4	S.E.6	Calm
Kingston	Calm	Calm	**E.3**	S.13	S.E.18	Calm

1878, *September.*

	24th.	25th.	26th.	27th.	28th.	29th.
San Juan	N.E.6	**S.E.11**	S.E.1	S.E.6	S.E.4	S.E.4
Navassa	N.W.12	N.N.E18	E.8	N.W.12	**S.25**	S.15
Santiago de Cuba	N.(1)	N.N.E.8	N.NE(1)	N.(1)	**NW(1)**	S.W.(1)

1879, *October.*

	10th.	11th.	12th.	13th.	14th.	15th.
San Juan	S.E.4	S.E.7	**S.E.0**	S.E.0	S.E.0	S.E.0
Navassa	N.E.5	E.10	S.E.16	**E.20**	S.E.15	S.E.18
Santiago de Cuba	N.7	N.2	**S.E.10**	S.E.6	S.E.8	S.E.6
Kingston	Calm	Calm	**S.E.4**	S.E.18	S.E.6	Calm
Nassau	N.E.	N.E.	N.E.	**E.**	S.E.	S.E.
Havanna	E.N.E10	E.6	E.N.E.8	E.12	**E.20**	S.S.E.18

It will be seen that in every case the passage of the low center was followed by a southerly wind, and in two-thirds of the cases this had been immediately preceded by a northerly wind; and in nearly every case the southerly wind which followed

the low area was stronger than the northerly wind which preceded it. This result, I believe, accords with what has generally been observed in tropical cyclones, and appears to suggest the explanation of the origin of the cyclone, and the direction of its progressive movement. The prevalent direction of the wind in the neighborhood of the West India Islands, is from the northeast. Occasionally a strong wind sets in from a southerly quarter. The interference of these winds gives rise to a gyration, and sometimes rain-fall is the result. When rain commences, the latent heat which is liberated, causes the wind to flow in from all quarters, by which the rain-fall is increased; and since the winds are deflected by the rotation of the earth, an area of low pressure is produced, and the force of the winds is maintained as long as the rain-fall continues. The effect of this strong wind from the south is to transport the low center in a northerly direction; and by the combined action of this south wind and the normal wind from the northeast, the center of low pressure is usually carried in a direction between the north and west.

The following summary presents some of the results derived from this investigation:

1. The lowest latitude in which a cyclone has been found near the West India Islands is ten degrees, and the lowest latitude in the neighborhood of Southern Asia is six degrees. Violent squalls and fresh gales of wind have however been encountered directly under the equator.

2. The ordinary course of tropical hurricanes is towards the west-northwest. In a few cases they seem to have advanced towards a point a little south of west, and in a few cases their course has been almost exactly towards the north.

3. Tropical hurricanes are invariably accompanied by a violent fall of rain. This rain-fall is never less than five inches in twenty-four hours for a portion of the track, and frequently it exceeds ten inches in twenty four hours.

4. Tropical storms are generally preceded by a northerly wind, and after the passage of the low center the wind generally veers to the southeast at stations near the center; and the southerly wind which follows the low center is generally stronger than the northerly wind which preceded it. This fact appears to suggest the explanation of the origin of the cyclone and the direction of its progressive movement.

5. None of the storms which have pursued a southeast course across the United States and its vicinity, have been traced further south than latitude 22½ degrees, and only three have been traced as far south as latitude 25 degrees. These storms during their progress southward generally decline in intensity. Some of them decline to such an extent that their course can

no longer be traced, while others change their course and turn towards the northeast. In my eleventh paper I have shown that storms which advance from north to south across the United States, are generally attended by a very slight fall of rain; and this seems to explain the fact that they generally decline in intensity as they advance southward.

Storms in the Middle latitudes advancing in a Westerly direction.

The infrequency of the cases in which tropical storms have advanced towards the southwest, has led me to search for corresponding cases in the middle latitudes of America and Europe. For this purpose I have examined all the cases in which the charts of the U. S. Signal Service indicate the movement of a storm center towards any westerly point. I have also examined Hoffmeyer's daily charts from Dec., 1873, to Oct., 1876; the charts of the Deutsche Seewarte from Jan., 1876, to March, 1879, and from Jan., 1880, to April, 1880; also the charts of the International Observations from Nov., 1877, to Dec., 1879. Many of the cases of this description which are shown on the charts of the U. S. Signal Service are cases in which the depression of the barometer was small, when there was no single well-defined storm center, but there were two or three centers of slight depression within a few hundred miles of each other, so that a slight change in the force of the winds would cause one of the centers to predominate a little, and thus the center of greatest depression might be carried in an unusual direction.

The following table shows the most decided cases in which storm-centers in the United States have advanced in a westerly direction:

Storms in the United States advancing Westerly.

No.	Date.	Latit'e. beg. end	Long. beg. end	Course.	Vel., miles.	Lowest barom.	Subsequent course.
1	1873. Oct. 20.1–21.3	39°–46°	75°–86°	N.W.	20·7	29·35	Unknown
2	1874. May 9.1– 9.3	49–42	97–104	S.W.	37·3	·29	N.E.
3	1876. Jan. 8.3– 9.1	44½–43	84–87	S.W.	22·2	·14	E.N.E.
4	Feb. 25.3–26.3	41–38½	95–97	S.[illegible]	8·5	·40	Eastward
5	June 17.3–18.2	44–47	86–88	N.	12·7	·37	Southerly
6	Sept. 16.1–17.3	25–41	77–79½	N.N.W.	28·8	·47	Eastward
7	1877. Feb. 21.2–22.1	48–41½	89–93	S S.W.	33·9	·35	Eastward
8	Nov. 22.3–24.3	32–42	79½–84	N.N.W.	15·7	·63	Disappeared
9	1878. Feb. 19.2–20.1	43–34	95–98	S.S.W.	43·0	·33	N.E.
10	Mar. 10.1–11.1	43–42	96–104	W.S.W.	18·0	·47	Eastward
11	Mar. 23.1–24.1	50–42	57½–72	S.W.	36·7	·22	E.N.E.
12	April 28.2–29.1	37–41	77–79½	N.N.W.	18·5	·58	Disappeared
13	June 22.2–23.1	42–44	76–79	N.N.W.	15·7	·60	E.N.E.

The number of these cases is 13; and 4 of these pursued a course about N.N.W.; 2 advanced towards the N.W.; 1 towards the W.S.W.; 3 towards the S.W.; and 3 towards the S.S.W. Case No. 1 was particularly noticed in my seventh

and eleventh papers. It was there shown that this storm was accompanied by an excessive fall of rain; also that the winds on the east side were uncommonly strong, and observations of the upper clouds indicated that these winds extended to an unusual height above the earth's surface. Nos. 5, 6, 8, 12 and 13 were also accompanied by a great fall of rain, especially No. 6, and in all of the cases the winds from the south and east were remarkably strong. This will appear more distinctly from the following table, in which column second shows the highest wind reported for cases 1, 5, 6, 8, 12 and 13 at the given dates from any quarter between N. and W.; and column third shows the highest wind from any quarter between S. and E.

Highest winds reported.

Date.	N. and W.	S. and E.	Date.	N. and W.	S. and E.
1873. Oct. 20.1	N. 28	S.E. 32	1877. Nov. 22.2	N.W. 25	S.E. 20
20.2	N. 36	E. 42	22.3	N.W. 16	S.E. 22
20.3	N. 28	S.E. 32	23.1	N. 15	S.E. 32
21.1	N. 32	S. 24	23.2	N.W. 16	S.E. 30
21.2	N. 20	S. 28	23.3	W. 12	E. 32
21.3	N. 32	S. 32	24.1	N.W. 12	E. 44
1876. June 17.3	N. 24	S.E. 29	24.2	N. 10	E. 42
18.1	N.W. 30	S.E. 32	24.3	N.W. 8	E. 28
18.2	N.W. 38	S.E. 24	1878. April 28.2	N. 20	E. 18
Sept. 16.2	N.W. 24	E. 24	28.3	N. 15	E. 14
16.3	N.W. 10	E. 32	29.1	N.W. 12	E. 30
17.1	W. 13	E. 24	June 22.2	N. 20	E. 48
17.2	N.W. 10	E. 16	22.3	N.W. 12	E. 40
1877. Nov. 22.1	N.W. 13	S.E. 32	23.1	W. 12	E. 17

The average of the greatest velocities for the northwest quarter is 19 miles per hour, and for the southeast quarter it is 29 miles per hour.

In the following table, column second shows the highest wind reported for cases 2, 3, 4, 7, 9, 10 and 11 at the given dates for any quarter between S. and W.; and column third shows the highest wind reported from any quarter between the north and east.

Highest winds reported.

Date.	S. and W.	N. and E.	Date.	S. and W.	N. and E.
1874. May 9.1	S.W. 30	N.E. 12	1877. Feb. 22.1	S. 21	N. 25
9.2	S. 32	N.E. 12	1878. Feb. 19.2	S. 27	N.E. 8
9.3	S. 40	E. 17	19.3	S. 22	E. 15
1876. Jan. 8.3	S. 25	N.E. 26	20.1	S.W. 32	N. 18
9.1	S.W. 18	N.E. 29	Mar. 10.1	S. 20	N.E. 40
Feb. 25.3	S. 22	N.E. 44	10.2	W. 30	N.E. 55
26.1	S. 14	N.E. 50	10.3	S. 11	N.E. 36
26.2	S. 24	N.E. 44	11.1	S.W. 8	E. 16
26.3	S. 18	N.E. 44	24.1	S.W. 22	N. 40
1877. Feb. 21.3	S. 21	N. 20			

The average of the greatest velocities for the southwest quarter is 23 miles per hour, and for the northeast quarter it is 29 miles per hour. There are several instances in which the mode of comparison here adopted does not fairly indicate the relative force of the winds on the opposite sides of a low center, especially when the low center happens to be situated near the margin of the Signal Service map, but the average of the results when the storms were advancing towards the northwest, and also when they were advancing towards the southwest, appears very decided, and seems to indicate distinctly that the centers of least pressure advanced in that direction towards which the winds pressed in with the greatest force.

In my first paper I gave the result of two years' observations, which showed that the average velocity of the wind on the west side of a low center (within the isobar 29·90) was 10·1 miles, and on the east side 8·3 miles; being 22 per cent greater on the west side than on the east side. We have now found that when a low center advances westward, the velocity of the wind is generally greatest on the east side of the low center. The progressive movement of storms probably depends upon meteorological conditions which prevail at a considerable distance from the low center. Hoffmeyer's charts and the International maps sometimes inform us what these conditions are. The following summary shows certain conditions which prevailed at each of the cases contained in the table on page 15, as far as is shown by the maps which I have received.

No. 3. High on the north and east (765) with low (735) near South Greenland.
No. 4. High on the northeast (775 to 785) with low (735) near Newfoundland.
No. 5. High on the east (770) with low (740) near Iceland.
No. 6. High on the northeast (775) with low (750) over the Atlantic.
No. 8. High on the northeast (30·40) with low (29·80 to 29·20) over the Atlantic.
No. 9. High on the east (30·20) with low (29·20) near Newfoundland.
No. 10. High on the northeast (30·60) with low (29·40) over the Atlantic.
No. 11. High on the north and northeast (30·20) with low (29·00) over Northern Europe.
No. 12. High on the north and northeast (30·20) with low (29·40) near South Greenland.
No. 13. High on the north and east (30·20 to 30·40) with low (29·60) near Iceland.

Thus we see that in the preceding cases there generally prevailed a considerable area of low pressure over the Atlantic Ocean, while on its western or northwestern side a cold wind from the north, with high pressure, was forcing its way southward, and this may be presumed to have crowded westward the low areas prevailing at the same time over the United States.

The following summary presents some of the conditions prevailing at these dates on the Western side of these low areas.

No. 1. Low center (29·70) on the Northwest side which gradually approached and coalesced with No. 1.
No. 2. Isobars protruded very much towards S.W.
No. 3. Isobars protruded very much towards S.W.
No. 6. Low center (29·50) on the Northwest side.
No. 7. Isobars protruded towards S.S.W.
No. 8. Low center (29·50) on the Northwest side.
No. 9. Isobars protruded to a great distance towards S.W.
No. 10. Low center (29·80) in the Gulf of Mexico.
No. 11. Isobars protruded to a great distance towards S.W.
No. 12. Low center on the N.W.
No. 13. Subordinate low center on the N.W.

Thus we see that while on the East side of these low areas there were causes which tended to increase the pressure on that side, there were different conditions on the Western side which tended to divert the winds Westward, and this is apparently the most important reason why, in these cases, the centers of least pressure advanced Westward.

Storms advancing Westerly over Europe and the Atlantic Ocean.

The following table shows the most decided cases in which storm centers have advanced in a Westerly direction over Europe and the Atlantic Ocean.

European storms advancing Westerly.

No.	Date.	Latitude. beg.	end.	Longitude. beg.	end.	Course.	Vel., miles.	Low't bar'm	Subsequent course.
1	1875. Mar. 14–16	50°	–46°	37°W.	–43½°W.	S.W.	8·3	730	Absorbed
2	Dec. 17–19	64	–64	29W.	–43W.	West	8·8	720	Easterly
3	1876. April 19–20	52	–56	3W.	–5W.	N.N.W.	12·2	735	N.E.
4	June 19–20	57½	–60½	23½W.	–27W.	N.W.	10·1	730	Subdivided
5	June 22–23	57½	–59	26W.	–33½W.	N.W.	12·1	740	Disappeared
6	Sept. 9–12	55	–60	21E.	–7E.	N.W.	8·0	735	Subdivided
7	Sept. 22–23	54½	–56	26½W.	–30W.	N.W.	6·7	740	Subdivided
8	Oct. 20–21	56½	–64	34½W.	–49W.	N.W.	28·7	720	Eastward
9	Nov. 12–14	50	–52	7W.	–16W.	W.N.W.	8·8	730	Northward
10	Dec. 21–23	53	–56	1W.	–8W.	W.N.W.	3·8	729	Southerly
11	1877. April 4– 8	56	–50	9W.	–13W.	S.S.W.	4·8	733	N.E.
12	May 3– 6	52	–64	44E.	–18E.	N.W.	17·2	744	Disappeared
13	July 15–16	54	–54	2W.	–5W.	West	3·4	737	N.E.
14	Aug. 9–9½	54	–57	0	–4W.	N.W.	19·2	745	Disappeared
15	1878. Mar. 31–32	59	–59	10E.	–0	West	14·3	729	North
16	May 30–32	60	–60	27E.	–17E.	West	7·1	741	N.E.
17	Nov. 4– 6	54	–59	25E.	–19E.	N.N.W.	8·6	737	N.E.
18	Nov. 11–13	59	–49	7E.	–3E.	S.S.W.	14·4	733	S.E.
19	Nov. 14–16	47	–54	10E.	–4E.	N.N.W.	11·5	734	South
20	Dec. 10–11	52	–56½	25E.	–23E.	N.N.W.	14·9	739	N.E.
21	1880. Feb. 16½–17	54	–56	7½W.	–10W.	N.W.	17·2	720	Unknown

The first eight cases are derived from an examination of Hoffmeyer's charts. Six of these cases occurred near the middle of the Atlantic ocean; one on the western borders of Europe, and the other in the eastern part of Europe. They are cases in which the depression of the barometer was consid-

erable; in which the low center was pretty sharply defined; and in which no neighboring low center is represented on Hoffmeyer's maps. Cases 9 to 21 have been derived from the charts of the Deutsche Seewarte, and all have been carefully compared with the International Observations, excepting No. 21, for which the International Observations have not yet been received. Of these 21 cases, 14 advanced towards some point between north and west, 3 advanced towards some point between south and west, and 4 advanced almost exactly west.

I have endeavored to compare the force of the wind on that side of each low area towards which the storm was advancing, with the force on the opposite side according to the observations delineated on Hoffmeyer's charts. The number of the observations over the Atlantic Ocean is so small that the results for that region are not entitled to much weight. The following shows the comparison of the observations within the isobar 750 for cases 3 and 6, the force of the winds being represented by the numbers of Beaufort's scale (0 to 6).

		Front.	Rear.			Front.	Rear.
1876.	April 19	1·76	2·27	1876.	Sept. 10	2·20	3·33
	Sept. 9	1·42	1·50		Sept. 11	1·83	2·87

Thus we see that on the rear of these low areas the average force of the wind was 38 per cent greater than on the front side.

The following summary shows the state of the barometer on the east side and also on the west side of storms Nos. 1–8 and Nos. 15–20.

	On the East side of the low area.	*On the West side of the low area.*
1	775 on the north and east increasing to 780 on the northeast.	29·4 to 29·0 in the United States. Isobars protruded westward.
2	735 on the east.	29·6 to 29·2 near Newfoundland.
3	770 on the east.	755 to 740 near Newfoundland.
4	765 to 770 on the east.	29·6 in the United States. Isobars protruded westward.
5	770 on the northeast side.	75[illegible] to 745 near Hudson's Bay.
6	770 on the east and 750 on the north-northeast.	765 to 770 on the west, with 755 to 735 near Newfoundland.
7	765 on the east and southeast.	755 to 750 on the northwest.
8	770 to 775 on the east.	Subordinate low (735) near South Greenland. Also 745 in the United States.
15	30·4 to 30·6 on the east.	29·7 to 29·4 near Newfoundland.
16	Barometer slightly below normal throughout nearly all of Asia.	29·7 near Greenland.
17	30·6 on the east.	30·2 falling to 30·0 on the west. Also 29·6 near Newfoundland.
18	30·4 on the southeast.	30·4 on the southwest.
19	30·4 on the east.	Subordinate low (29·4) on the northwest side; also 29·1 in Greenland.
20	30·8 to 31·0 on the east.	29·8 to 30·0 on the west and northwest.

In all but two of these cases there was an area of high pressure on the east side of the storm center, and in several of the cases this pressure was above 30·5 inches. Such a pressure is

sufficient to produce a wind of considerable force. On the west side of these storm centers there was generally a second area of barometric depression, and in several cases the two depressed areas approached each other until they coalesced, by which means the eastern low center was apparently transported westward. Nos. 1, 2, 8 and 19 were of this description, and probably also No. 5. In several other cases the two low areas approached each other until they formed a single low area of an elongated form, with two low centers which remained for several days distinct from each other. Such were Nos. 3, 4, 7 and 15. In No. 6 the storm was apparently diverted Northward by the low area on the north-northeast. In No. 16 the pressure was generally below 30 inches throughout north America, the North Atlantic Ocean, as well as Europe and Asia. In such a case, slight local causes are sufficient to divert the winds in a new direction. In No. 17 there was apparently an area of low pressure on the north beyond the stations of the International Observations. In No. 18 there was a high area on the southeast and another on the southwest, and the low area pushed in between them. In the United States it is frequently observed that when two areas of high pressure approach within a few hundred miles of each other, a low center is developed between them. A similar case occurred in No. 6 between Sept. 11th and 12th. In No. 20 the observations do not indicate any decided low center on the north or west, yet the pressure was every where either below or but little above the normal over the North Atlantic Ocean and North America.

Thus we see that in Europe and over the Atlantic Ocean as well as in the United States, the influence of one area of low pressure upon another is a very common cause of abnormal movements of storm centers.

In preparing the materials for this article I have been assisted by Mr. Henry A. Hazen, a graduate of Dartmouth College of the class of 1871.

NOTE.—Since the preceding was in type, I have received Hoffmeyer's charts for November, 1876, from which it appears that on the 12th of November, 1876, there was an area of low pressure (730 to 725) west of Ireland; and the apparent westward movement of No. 9 on page 18 was plainly due to the influence of this low center. I have also received the International Bulletin for October, 1880, from which it appears that on February 16th there was a low center (28·40) west of Ireland, and the apparent westward movement of No. 21 on page 18 was plainly due to the influence of this low center.

ART. II.—*The Albany Granite, New Hampshire, and its Contact Phenomena;* by GEORGE W. HAWES, New Haven.

IN the studies that have been directed to the end of discovering the nature and origin of our great granitic masses, the contact phenomena have received but little attention. The application elsewhere of the modern methods of lithological research to the rocks upon the limits of granitic masses has, however, been fruitful in developing facts of geological interest. The study which I present indicates that no more striking phenomena have been observed anywhere than those which are found upon the boundaries of one of the New Hampshire granitic masses. These phenomena have additional interest since they occur in a region of highly crystalline schists, which usually are not susceptible to influences of this nature. In the Vosges, for example, the granites, which have produced the most marked and wide-reaching effects upon clay slates, have had no influence upon the crystalline schists which they have intersected.* As the New Hampshire granite here considered exhibits very striking modifications in character, dependent upon the neighborhood of the contact, and as a spot was found where the arrangement of the rocks is favorable for a careful consideration of the effects of the contact both upon the schists and the granite, I have investigated these rocks with a view of presenting this study as a contribution to White Mountain Geology.

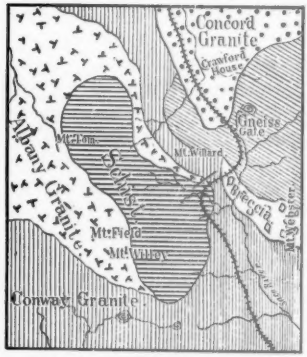
The line of contact between the Albany granite and an area of argillitic mica schist crosses Mt. Willard in the Crawford notch. The normal rocks with their contact modifications are familiar to many of our geologists. The beauty of the natural scenery, combined with the geological interest, has attracted many to this spot, and these rocks have accordingly had frequent mention. For the opinions in regard to the nature and origin of the granites at this point, and the interpretation of the effects that are due to the contact, I refer to the second volume of the Report on the Geology of New Hampshire, by Professor C. H. Hitchcock. As the relation of these peculiar rocks to one another, and the nature of the changes that they have undergone, can however be discovered only by chemical and microscopical study, it is neither necessary nor just to submit to critical consideration the opinions formed without the aid of these methods.

The general arrangement of the rocks upon Mt. Willard is

* H. Rosenbusch, Abhandlungen zur geologischen Special Karte von Elsass-Lothringen, Bd. I, Heft II, p. 89.

shown in fig. 1.* Although but a small mountain several of the most characteristic New Hampshire granites take part in its composition. In this paper it is proposed to confine the attention to the Albany granite,† which forms an immense mass covering many square miles to the west, but which crosses Mt. Willard in the form of a dike about three hundred feet wide. The Conway granite, a coarse-grained biotite granite, forms the hanging wall, and argillitic mica schists form the foot wall of this dike. Mt. Willard presents a bold cliff nearly a thousand feet high toward the south, and the contact lines of these three rocks run diagonally across this cliff, exposing themselves most favorably for study and observation. We have here then a small and narrow granitic mass which is connected with a great mass, and this forms in a modified way a parallel to the celebrated "Bodegang," which is a small narrow dike that connects the Ramberg and Brocken, two granite mountains in the Harz, the phenomena connected with which have been described by Lossen.‡

1.



Map of the Mt. Willard region. Scale 2½ miles to one inch.

The Albany granite is a very distinctly and definitely characterized rock. It is called by Hitchcock the spotted or trachytic granite.§ In all its areas it has the same peculiar

* This map is essentially a reproduction from the large geological map of New Hampshire, prepared by Professor C. H. Hitchcock, and forming a part of the atlas accompanying his geological report. Under his direction the area marked "breccia granite" has been added. This is a distinct granite mass which includes in certain portions immense blocks of gneiss. Such inclusions occur in the granite elsewhere in New Hampshire, and are also known abroad. The figures on page 225 in vol. i of Naumann's Geognosie, drawn from a cliff on the Einank in Norway, might just as well have been drawn from a cliff in the Crawford notch. It is to the granite which *includes* these fragments that Professor Hitchcock has given the title of breccia granite. Upon his geological map he has considered the Albany and the Conway granites as eruptive, and the Concord as metamorphic. In this paper I deal simply with the Albany granite, and introduce this map to show the relationship in which the schists and this granite stand with reference to one another, and especially the form of the area occupied by the Albany granite. If contact phenomena take precedence over details of internal structure, the origin of all the other granites including the Concord granite and the gneiss are open questions.

† So named by Professor Hitchcock on account of its extensive development in Albany, N. H.

‡ Zeitschr. d. d. Geol. Ges., 1874, p. 856.

§ For distribution of this granite see Hitchcock's Geol. New Hampshire, vol. ii, p. 143.

appearance due to the development of Carlsbad twins of orthoclase with rounded contours, in a gray fine-granular aggregate of granitic minerals, which are said to form a mixture resembling pepper and salt. Whether red or white, it is equally characteristic in appearance, and from its extensive development it is to be considered as one of the important granitic masses of New England.

Nor in its microscopic characters is this granite less characteristic. Its twin crystals of feldspar in polarized light are seen to have the peculiar structure of perthite, and consist of interlaminated orthoclase and albite.* Individual grains of a triclinic feldspar are often seen. The quartz is in formless grains and possesses the usual fluidal inclusions, and the position in angular corners due to the order of crystallization. The chief accessory is hornblende which is black in the rock, but green, yellow, dichroic, in thin sections, and peculiarly impure from the enclosure of quartz grains. Biotite, magnetite and apatite are constant, augite and fluor spar are frequent, constituents.

But what gives to this rock a very marked microscopic individuality is the uniform presence in it of well-crystallized square prisms of zircon. Of the many sections that have been cut, not one has been found free from these pretty crystals. They are large enough to be examined optically under the microscope, and are easily recognized by their tetragonal crystallization, their high index of refraction. Their uniaxial and positive character can be easily determined in convergent light. Out of twenty-five grams of the rock from Mt. Willard, I separated several hundred of these crystals, by means of hydrofluoric acid. They are white, clear and glassy, but are sometimes tinged with yellow. They are often $\frac{1}{10}$ mm. in diameter and $\frac{4}{10}$ mm. long. Their surfaces are bright, but cavities often penetrate far into their interiors. They are doubly terminated, and in addition to the planes of the prism and pyramid of the first order, they frequently have the planes of a ditetragonal pyramid which is probably the form 3–3. They contain many inclusions. Some of these are the inverted forms of zircon crystals, some are zircons with different terminal faces, and some are empty cavities with very irregular forms.

In the middle of the arm of Albany granite which extends across the summit of Mt. Willard, the rock is of this normal character, but both to the right and the left differences are evi-

* Sections parallel to the base hardly show these interlaminations owing to the approach in the elasticity planes of the two species. Sections parallel to the clino pinacoid possess an elasticity plane making an angle of 6° with the basal cleavage, and in the interlaminations an elasticity plane makes an angle of 17° in the same direction, with the basal cleavage.

dent. These differences are of the same character upon both sides, but they are very much more marked upon the side of the schist. At a distance of 100 feet from the contact, the crystals that form the granite have become smaller with the exception of the large feldspar crystals, which are in consequence more conspicuous. At a distance of sixty feet a tendency in the quartz to assume crystalline forms is noticed, and the rock begins to appear porphyritic. At fifteen feet from the contact with the schists, the quartz is found in well-defined dihexagonal pyramids, as large as peas, and these with the Carlsbad twins of orthoclase are imbedded in a ground mass no longer resolvable by the unaided eye or lens. Upon the contact the ground mass is nearly black in color, flinty in texture, and apparently homogeneous. The Albany granite has become a quartz porphyry.*

The accompanying microscopic changes are as striking. Approaching the contact there is a continual diminution in the amount of the hornblende and the size of its crystals. There is a corresponding increase in the amount of the biotite, which finally entirely replaces the hornblende. These biotite crystals are at first quite large, but they diminish rapidly in size near the contact, and upon the contact are reduced to a dust. The ground-mass which makes its appearance between the quartz and orthoclase crystals, grows finer, but upon the contact though of extreme fineness, it is still entirely crystalline. In this ground-mass all the minerals of the granite found in specimens distant from the contact are recognizable, but near the contact no individual crystals can be determined.

In this series of changes all the minerals have taken part with two exceptions. The Carlsbad orthoclase twin crystals and the zircon crystals have the same shape and size in all parts of the rock. That is, with these exceptions the condition or existence of the mineral components depends upon position with reference to the contact.

These modifications, which are repeated in a less conspicuous manner upon approaching the contact with the granite upon the opposite side of the mass, are such as might be induced in a molten eruptive mass, which, like modern lavas, contained some crystals already formed at the time of eruption by the effect of contact with cold walls, the hydrous nature of

* The Bodegang previously referred to is filled with quartz porphyry which however has a coarser ground mass in the center.

In the Vosges the granites which have altered the slates are upon their side usually unaffected. At one spot however in the Weihermattenthal the granite became porphyritic upon the contact. Rosenbusch, Die Steiger Schiefer und ihre Contactzone an den Granititen von Barr-audlan und Hohwald, p. 156.

In the Pyrenees near Case de Brousette a contact occurs between clay slate and a porphyry which farther south gradually changes into granite. Zirkel, Zeitschr. d. d. Geol. Ges., 1867, p. 106.

one and the anhydrous nature of the other being factors modifying the extent of the effect.

Any chemical changes that may be connected with these modifications are represented in the following table of analyses.

	Normal Albany Granite.	Granite Porphyry 3 ft. from contact.	Granite Porphyry 2 in. from contact.
SiO_2	72·26	73·09	71·07
Al_2O_3	13·59	12·76	12·34
Fe_2O_3	1·16	1·07	2·25
FeO	2·18	4·28	4·92
MnO	*tr.*	·08	*tr.*
CaO	1·13	·30	·55
MgO	·06	·09	·19
K_2O	5·58	5·10	5·53
Na_2O	3·85	3·16	2·84
TiO_2	·45	·40	·27
H_2O	·47	·73	·72
	100·73	101·06	100·68
Sp. Gr.	2·65	2·66	2·68

Of the differences here shown some fall within the evident errors of the analyses; and so many of the others can be referred to differences introduced in sampling such coarse-grained compounds, that I do not think that any changes can be definitely referred to the effect of contact, unless it be the accession of iron, and the slight hydration. If we assume that no chemical change has taken place, and that the first analysis represents the whole, a calculation shows that it may contain:

	Quartz.	Orthoclase.	Albite.	Anorthite.	Hornblende.	Biotite.	Magnetite.	Titanic Iron.
	25·99	32·95	32·61	1·35	4·83	---	1·68	·85
Or,	26·79	30·76	31·01	5·65	---	5·44	---	·85

The biotite has the composition $(K,Na)_2(Fe,Mg)_4AlSi_4O_{16}$ (= one molecule K and one M of Tschermak) and the hornblende will be $11(R\,SiO_3)+Al_2O_3$. This calculation can not claim to be accurate since there are no data for dividing the lime between the anorthite (which is supposed to be combined with some of the albite to make a triclinic feldspar) and the hornblende. It is introduced to show that the results of the chemical investigation do not at all contradict the microscopic results, since a recrystallization and a rearrangement in the proportions between the feldspars, furnishes all the material necessary to convert the hornblende into biotite.

The schists that occupy the area indicated upon the map, form portions of Mts. Tom, Field, Willey and Willard, elevations in the vicinity of the White Mountain Notch. Their age is unknown. Their reference to the Silurian on account of a supposed fossiliferous character being based upon an error, it is only certain that they are older than both the Albany and the Conway granites, both of which intersect them. In composition they

are not at all constant, but the prevailing variety is a dark compact argillitic mica schist with andalusite crystals scattered through parts of it. Upon the summit of Mt. Willard they appear to be very uniform over a large area, and for this reason the specimens for chemical study were taken from this spot.

The schists at the summit have a strike very nearly north and south, and they dip 60° to the west.* The line of contact with the granite runs in an irregular northwest direction. At a distance of 100 feet from this contact, with the exception of the rather rare andalusite crystals, no minerals are visible in this schist to the unaided eye, unless the glistening surface be considered as an indication of mica. Under the microscope it is seen to consist of quartz, muscovite (probably the variety containing combined water), and chlorite. Titanic iron partially decomposed into leucoxene, some magnetic iron which can be drawn from the powder with a magnet, and particles resembling coal or graphite, constitute opaque black ingredients. A little biotite and a very few crystals of tourmaline, recognized by form and the direction of strong absorption, are accessory constituents. No marked change is visible in the rock at a distance of fifty feet from the contact, but nearer than this point the effect of the contact becomes very soon evident. As the specimens described and analyzed were all, with the exception of the normal schist at 100 feet, taken from the same stratum, I think that all the differences noted may be with certainty regarded as due to the effect of contact.

Twenty-five feet from the contact the schists are much changed in microscopic structure. They are more definitely and coarsely crystalline; biotite becomes a more prominent constituent, and tourmaline crystals, blue within and brown without, have become a prominent constituent.

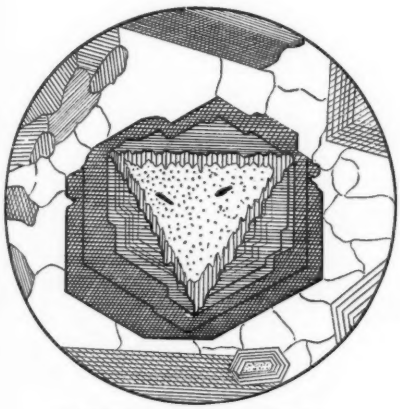
Between this point and the contact the changes apparent to the eye are marked and rapid. At fifteen feet, the rocks are still schistose, but they are hard, much fractured, and full of shining dots that indicate a new crystallization. At this point the rock is a mica schist. Under the microscope, a decrease in the amount of chlorite and an increase of biotite are noted, also the presence of many tourmalines and of large clear quartz grains with fluidal enclosures. The titanic iron is entirely altered into a dull white opaque substance.† Between this point and the contact the schist loses entirely its schistose

* Strike of slate 12–22 W., strike of contact N. 77 W. Hitchcock's Geology of New Hampshire, vol. ii, p. 177.

† I can not regard the conclusion of Prof. v. Lasaulx that this substance is titanite of lime, titanomorphite, as certainly correct in all cases, for in rocks like this that are nearly free from lime the same decomposition takes place. In this case there is not enough lime in the whole rock to make titanomorphite with the titanic acid.

structure, and is converted into a black hornstone, which breaks into small angular fragments. The little bright crystalline grains of quartz increase in quantity, and the tourmalines become much more numerous. From the schists ten feet from the contact a qualitative reaction for boric acid can be obtained. The rock, which thus far has been growing coarser in texture, from this point grows gradually finer, and is converted near the contact into flinty, compact hornstone, thin sections of which are resolved by the microscope into an aggregate of quartz, biotite, tourmaline, and iron oxide.

2.



Section of tourmaline veinstone.
× 100 diameters.

But between this hornstone and the granite another well defined zone exists. This is a dark-gray mass which is filled with reticulated black veins. Scarcely noticeable on the top of the mountain, this zone becomes wide and prominent below. The veins which fill this mass divide and subdivide, giving to the whole a fused, slaggy appearance. Under the microscope, however, this mass is resolved into a nearly pure mixture of tourmaline and quartz. While in the hornstone zone last described, the tourmalines are in extremely minute formless grains, here they are in more or less well defined crystals, and possess a concentrically banded structure. White, blue, light brown and dark brown layers follow one another in the order named. Fig. 2 (× 100) represents a section possessing these zones. These crystals are bounded by the planes $-\frac{1}{2}\,\mathrm{R}.\,-\frac{i\,\mathrm{R}}{2}.\,i\,2$. This mass I characterize as the zone of the tourmaline veinstone to distinguish it from the last, or the zone of the tourmaline hornstone. There is reason for this in the circumstance that the impregnating material has wholly altered the character of the schist.

The chemical changes that have taken place, both in ultimate composition and mineral constituents, are indicated in the following table of analyses:

	Schist 100 ft. from contact.	Schist 50 ft. from contact.	Schist 15 ft. from contact.	Tourmaline Hornstone 1 foot from contact.	Tourmaline Veinstone on contact.
SiO_2	61·57	63·35	66·30	67·88	66·41
Al_2O_3	20·55	19·69	16·35	14·67	16·84
Fe_2O_3	2·02	·72	·95	2·37	1·97
FeO	4·28	5·48	5·77	3·95	5·50
MnO	·10	·16	*tr.*	·11	·12
CaO	·24	*tr.*	·24	·30	·37
MgO	1·27	1·77	1·63	1·29	1·71
K_2O	4·71	3·47	3·40	4·08	·56
Na_2O	·68	1·12	1·11	3·64	1·76
TiO_2	1·10	1·00	1·28	·93	1·02
B_2O_3	----	----	*tr.*	·97	2·96
Fl	----	----	----	*tr.*	·25
H_2O.	4·09	3·73	3·02	1·01	1·31
	100·61	100·49	100·05	101·20	100·78
Sp. Gr.	2·85	2·84	2·82	2·74	2·73
Quartz	36·87	39·17	45·15	50·82	50·03
Muscovite	49·30	44·53	} 43·89	} 29·67	----
Biotite	----	----			
Chlorite	8·62	13·70	6·65	----	----
Titanic iron	2·09	1·90	2·43	1·77	1·94
Magnetite	2·93	1·04	1·38	3·44	2·86
Tourmaline	----	----	----	14·92	45·95
Excess of H_2O.	·80	·15	·55	·58	----
	100·61	100·49	100·05	101·20	100·78

In these analyses a systematic and progressive series of changes indicates that there has been an addition to the schists by reason of contact with the granite. The dehydration, and the accession of boric and silicic acids are positive features, and the addition of alkali directly upon the contact, in consideration of the circumstance that the second, third and fourth samples were taken from the same stratum, may be regarded as certain also. The series of analyses given by Professor Rosenbusch in his work upon the contact phenomena in the Vosges* prove, in his opinion, that, whatever may have been the physical changes, nothing (except in one case a little boric acid) has been added to the schists, and the analytical results obtained by others from contact schists lead to the same result. The kind of changes indicated by my analyses, if of less degree, are of the same kind as those that have been observed in the contact of granites with limestones, as for example in the Harz where the limestones about the Ramberg† have their CO_2 replaced by SiO_2, forming a broad zone of lime silicates about the contact; and on the contact of limestone with Monzonit‡ at Predazzo, where a similar lime-silicate hornstone zone is found to be rich in alkali directly upon the contact.

* Die Steiger Schiefer und ihre Contactzone. Strassburg, 1877, p. 257.
† Lossen, Zeitschr. d. d. Geol. Gesellschaft, xxiv, p. 777.
‡ J. Lemberg, Zeitschr. d. d. Geol. Gesellschaft, xxiv, p. 234.

The effect of the contact becomes much more striking when the percentages of the constituent minerals are calculated from the analyses. This was done in the first two analyses as follows. The titanium dioxide was first reckoned into titanic iron, and the iron sesquioxide calculated into magnetite, since the magnet attracts black particles from the powder. The remaining iron protoxide, with the manganese oxide, and the magnesia were then calculated into a chlorite of the formula of ripidolite ($Mg_5Al_2Si_3O_{14}+4H_2O$). Then if the remainder of the alumina is calculated into muscovite ($(K,H)_2Al_2Si_2O_8$), nothing at all is left save the small percentages of water indicated in the table, which are not much more than what may be supposed to be hygroscopic, or included. In the third analysis, the protoxides before calculated as belonging wholly to chlorite have been divided equally between chlorite and biotite in accordance with the microscopic indication. The tourmaline hornstone is a nearly pure mixture of tourmaline and quartz, as shown by the microscope, hence in the last analysis, after calculating the amount of titanic iron and magnetite, the remaining bases were calculated as forming a tourmaline of the formula $\begin{cases} m\,\dot{R}_6SiO_5 \\ n\,\dot{R}_3SiO_5. \\ r\,\ddot{R}\,SiO_5 \end{cases}$ In accordance with this the composition of the tourmaline is as follows:

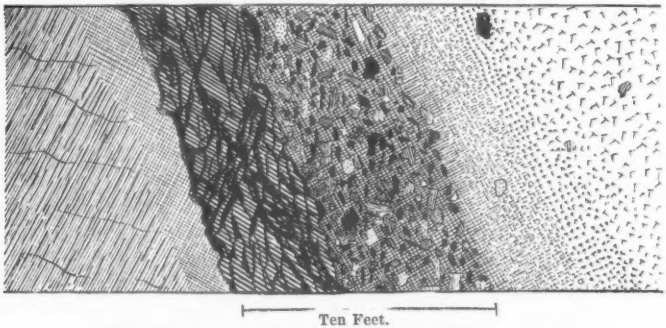
SiO_2	Al_2O_3	FeO	MnO	CaO	MgO	K_2O	Na_2O	H_2O	B_2O_3	Fl
35·65	36·66	8·03	·26	·79	3·72	1·22	3·83	2·85	6·45	·54 = 100

The fourth analysis can now be calculated like the third, after deducting the percentage of tourmaline calculated from the boron trioxide. If biotite is considered as a combination of the muscovite molecule $(K,H)_2AlSi_2O_8$ with the molecule $Mg_4Si_2O_8$ (according to Tschermak) we have the data only for obtaining the sum of the muscovite and biotite, but not the amount of each. If the data of these calculations are not absolutely correct, the results agree well with the microscopic observations, and the table I think indicates clearly both the chemical and mineralogical changes, and make it plain that they are progressive in approaching the granite.

Just between the schist and granite, upon the summit of the mountain, a very insignificant zone exists which consists of granite in which numerous fragments of a variety of rocks are included. This zone, scarcely noticeable upon the summit, becomes larger and better defined as one descends the cliff, and I shall show what a weighty part this little zone, here but a foot or two wide, plays elsewhere. This zone I call the *mixed zone*. At a short distance below the summit it becomes a very sharply defined band three feet wide, and consists of fragments of various kinds of schist, and angular fragments of

a foreign variety of quartz porphyry, and all are cemented together with the granitic material. The feldspar crystals in this granite are all broken to fragments,* and the whole mass is impregnated with tourmaline, but the constituent minerals

3.



Junction of Argillitic mica schist and Albany Granite.

are all easily recognized. Fig. 3 illustrates the appearance of the contact, as seen upon the cliff at an easily accessible point, about 150 feet below the summit. The different zones that I have described are here all sharply defined. To recapitulate, these zones are as follows:

1. Zone of the argillitic mica schist (chloritic).
2. Zone of the mica schist (biotitic).
3. Zone of the tourmaline hornstone.
4. Zone of the tourmaline veinstone.
5. Zone of the mixed schists and granite.
6. Zone of the granite porphyry (biotitic).
7. Zone of the granite (hornblendic).

It will thus be seen that the succession of zones is different from those that have been described about other granitic masses, but that the effects observed are of the same nature and referable to the same causes.†

Following the line of contact down the cliff, the phenomena of the contact ever become more extensive and remarkable. At a point just above the spot figured, a long arm of the porphyritic granite, from two to three feet wide and eighty feet long, extends into the schist at nearly a right angle to its

* The crystals of orthoclase found in the small branches of granitic masses where they would be subjected to friction have been often found broken. In the Fichtelgebirge and Elba for example. Credner Geologie, p. 285.

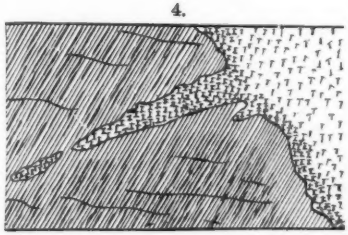
† The zones in the Vosges as described by Rosenbusch are

1. Clay slate.
2. Knotty clay slate.
3. Knotty mica schist.
4. Hornstone, usually Andalusite hornstone.

The knotty character is here entirely absent.

stratification. This arm is shown in fig. 4. The impregnation of the schists with tourmaline has been much more effectual below than upon the summit. Two hundred feet below the summit the schists distant 100 feet from the contact contain as many tourmalines as at fifteen feet from the contact upon the top. The mixed zone steadily increases in width as it descends, and at the base of the huge cliff it is more than twenty feet wide.

4.



Junction of schist and Albany granite, showing extension of the granite into the schist. Scale 75 feet to one inch.

These are the main features of this remarkable contact. I think they show that the Albany granite is an eruptive mass younger than the Conway granite, and younger than the andalusite schists, and that the main portion of its mass had not crystallized at the time of eruption. The inclusion of such varied products in the mixed zone indicates that it moved no inconsiderable distance through fissures in very diverse rocks. The kind of impregnation indicates that it was accomplished by vapors and solutions that emanated from the fissures filled by the granite; but the impregnation of schists embedded in the granite, and the impregnation of the schists attendant with a dehydration of the same, indicates the action of very hot vapors which accompanied the eruption; not the action of vapors subsequently emanated through the cleft.*

The line of division forming the contact is microscopically fine. Over this line the minerals of schist or granite do not pass except in the form of inclusions. There is therefore no relationship between the schist and the granite.

These results are of importance in White Mountain geology since the effects are often repeated. All about this area, and other areas of Albany granite as far as observed, the effects of the contact are found upon the edges of the granite. At Bemis Brook the same apparent effects are seen on the side of the granite, but the schists, which are hard siliceous mica schists, have not been affected. The porphyry which at this

* In the Vosges andalusite is the mineral characteristic of the contact, and the question having been raised whether andalusite ever occurs save as a contact mineral, this has been considered. The apparently systemless method of distribution of andalusite crystals over the whole area gives no basis for referring these macled crystals to the effect of contact.

The cavities in the quartz of the granite contain most variable amounts of fluid. Some are full and some are empty. The calculation of temperatures and pressures upon measured size of bubble and cavity can be of little value when, as is here plain, other unknown quantities beside those commonly considered are factors.

spot adjoins the schist has the granophyre* structure. This structure may therefore be induced as a contact phenomenon.

Ascending Mt. Kearsarge by the bridle path from the Intervale station, the base of the mountain is seen to be composed of Conway granite.† At a height of 500 feet one finds the peculiar gray porphyry with Carlsbad twins of orthoclase and dihexagonal pyramids of quartz, as on Mt. Willard, and which we recognize as the zone of the quartz porphyry, which gradually changes and finally becomes typical Albany granite. Here again we see that the Conway granite was a cool body influencing the crystallization of a later eruption. After climbing for a short while over the Albany granite, the zone of porphyry again appears; then follows in proper sequence the mixed zone, but this zone which upon Mt. Willard attains to a width of twenty feet, here forms the whole grand mass of Kearsarge, Bartlett and Moat Mountains. These mountains from base to summit consist of angular pieces of schists intermingled with and cemented by granite porphyry. The schists have been modified by the contact but to a less degree, since there has been here no impregnation with tourmaline. The mixed mass adjacent to the schists consists of a very large amount of broken schist, cemented by a small amount of the granite, which has been accordingly much modified by the effect of the schist, and has a ground mass very fine in texture, and homogeneous and flinty in appearance. Above, where there is a smaller proportion of schist in the porphyry, this ground-mass becomes more coarsely crystalline, and approaches granite in texture. The microscopic peculiarities however remain constant and the large zircon crystals never fail.

I have endeavored to show that the contact phenomena connected with the Albany granite are very beautifully developed upon a small scale, affording thus exceptional facilities for study and observation; but that on the other hand they reach an unequalled grandeur of proportion. The evidence previously offered by others has not been decisive in determining the eruptive or metamorphic origin of this rock, and I point to the fact that many other important granitic masses have been referred to the one or the other of these groups upon the same insufficient evidences of structure and internal stratification. From observations incidental to this work I am, however, quite certain that the study of the contact phenomena of the other great granitic masses in New Hampshire would develop as many interesting lithological facts, and furnish the proper evidence for a determination of their origin.

* Used in the sense of Rosenbusch. That is, the quartz and feldspar of the ground mass are arranged with reference to one another, as in graphic granite.

† See also Atlas to the Report on New Hampshire Geology, Hitchcock.

ART. III.—*A Theory of the Constitution of the Sun, founded upon Spectroscopic Observations, original and other;* by CHARLES S. HASTINGS.

FRAUNHOFER discovered the lines in the solar spectrum, known by his name, in 1814. Many efforts to determine their origin followed. One of the most ingenious and carefully considered was that of Professor Forbes in 1836.* He concluded that, if their origin is in the solar atmosphere, the light from the limb must exhibit stronger lines than that from the center. His method was to examine the spectrum before and during an annular eclipse; as he found no recognizable change, his deduction was, "that the sun's atmosphere has nothing to do with the production of this singular phenomenon."

The point was again touched upon by Sir David Brewster and Dr. Gladstone in a joint study of the spectral lines, published in 1860.† Here "each of the authors came independently to the conclusion that there is no perceptible difference in this respect between the light from the edge and that from the center of the solar disk."

In 1867 Ångström‡ repeated the experiment with negative results. Lockyer's‖ efforts also, in 1869, were attended with no better results.

In 1873, four years later, I devised and made an apparatus by which a perfect juxtaposition of the spectra of the center and limb was secured. This apparatus and certain of the results gained by its use were described in a note "On a comparison of the Spectra of the limb and the center of the Sun," published in this Journal, vol. v (1873), pp. 369–371. I was then a student at Yale College and soon after left New Haven, when the research was necessarily interrupted. I hoped, however, that the novelty and interest of the observations might lead others, possessed of the necessary apparatus, to develop the results of this method of investigation. But as nothing has been published on this subject since that time, I was glad to have an opportunity to continue the investigation in the summers of 1879 and 1880. The results of my labor are embodied in this paper.

The method adopted in the recent observations is exactly the same as that described in the article cited; instead, however, of the equatorial of the Sheffield Scientific School, I used a Clark equatorial of 9·4 in. aperture and 120 in. focal

* Notes relative to the supposed Origin of the Deficient Rays in the Solar Spectrum. Phil. Trans., 1836, pp. 453–456.

† On the Lines of the Solar Spectrum. Phil. Trans., 1860, pp. 149–161.

‡ Phil. Mag., 1867, p. 76. ‖ Proc. R. S., vol. xvii, p. 350.

length, which was kindly placed at my disposal by the gentlemen in Hartford, to whom it belongs.* The New Haven spectroscope too, of 12 effective prisms, was replaced by one of which the dispersing member was a Rutherfurd grating on speculum metal, either of 8648 or 17296 lines to the inch at will. These gratings were of the largest size, having a ruled surface of about $1\frac{3}{4}$ inches square.

The immediate results I give in order of refrangibility of the lines observed, as no observed variations in them can be attributed to anything other than the temporary modifications of transparency in our atmosphere. The numbers are the places on Ångström's maps as nearly as could be ascertained without micrometer.

Line (C) 6561·8 is cleaner and wider at limb, i. e. the haze on either side of the line as ordinarily seen is much reduced.
6431 is slightly stronger at center than at limb.
6371 is visible at center but not at limb.
(D_1) 5894·8 slightly less hazy at limb.
(D_2) 5889·0 decidedly cleaner at limb.
A fine line very close to its more refrangible side is either wanting or much fainter in spectrum of limb.
5577·5 is much stronger at limb.
5440 ± (not on Ångström's chart) is a little stronger at limb.
The Mg lines 5183·0, 5172·0, 5166·5 ($b_1 b_2 b_4$) are cleaner at limb. The line b_3 belonging to a different element does not show such a peculiarity.
5045 (a faint line not in Å.) is stronger at limb.
4919 ±, a faint line slightly stronger at limb.
(F) 4860·6 is much cleaner, more free from haze at limb.
4702·3 seems cleaner at limb.
4340·0 cleaner at limb.
4226·4 shows less haze at limb.
4101·2 is a very hazy line, so represented by Ångström; but at limb it is practically free from haze—a striking difference.
4045 is slightly less hazy at limb.

Other differences have been recorded, but only these have been observed more than once each.

Any theory of the sun, worthy of attention, must not only explain the above described phenomena, but also others better known, and as yet not accounted for satisfactorily. Of these the most noteworthy is the spectroscopic appearance of a spot and its penumbra. As is well known, such a spectrum exhibits a very strong general absorption, with a very slightly modified elective absorption. A few faint lines appear in the spot spectrum which are not otherwise seen; and a few faint

*My acknowledgments for this courtesy are gratefully accorded to Mr. Edgecomb its former owner, and to Mr. Howard and Mr. Chapin its present owners.

lines of the ordinary spectrum are strengthened. A careful examination has persuaded me that the spectrum of a spot differs from that of the unbroken photosphere, just as the spectrum of the limb differs from that of the center of the disk, save that the variations are more pronounced. Indeed, I could have considerably extended the list of lines strengthened at limb by an examination of the spot spectrum, where the variations appeal to the eye more clearly.

The accepted theory of the spots attributes the phenomenon to the absorption of the solar light by cooler, denser gases of the same nature as those producing the Fraunhofer lines. Familiar experiments teach, however, that as the density of a gas increases, the change in the character of its radiation is shown in its spectrum by the broadening of its distinctive spectral lines, which at the same time grow more ill defined. Therefore it follows that, according to the law connecting radiation and absorption, dark lines produced by such a gas must also, under similar conditions, show increased breadth and diminished sharpness. That no such changes are to be recognized is a fatal objection to the theory.

Another class of unexplained phenomena is the duplicity of certain lines of the solar spectrum, lines which are single in the spectra of terrestrial sources. Of these Prof. Young has discovered E_1, b_3 and b_4 with others.

My own observations can be arranged very simply in classes, and will then better lend themselves to theoretical discussion.

I. The most important fact of all is that the differences in the two spectra of center and limb are extremely minute, escaping all but the most perfect instruments, and all methods which do not place them in close juxtaposition.

II. Certain lines, the thickest and darkest in the spectrum, notably those of hydrogen, magnesium and sodium, which appear with haze on either side, in the spectrum of the center of the solar disk, are deprived of this accompaniment in that of the limb.

III. Certain very fine lines (four observed) are stronger at limb.

IV. Other very fine lines (two or three observed) are stronger at center.

The ordinarily accepted theory of the origin of the Fraunhofer lines fails to explain the phenomena as observed. That is, if we suppose the photosphere, whether solid, liquid, gaseous, or cloud-like, to yield a continuous spectrum which is modified only by the selective absorption of a surrounding atmosphere, then the absorption must be greater at the limb than at the center of the solar disk; and this must be true independently of the thickness of that atmosphere as well as of

the form, rough or otherwise, of the surface of the photosphere. This evident consequence, pointed out in the first place by Forbes, nearly half a century ago, cannot be avoided. There is but one way of maintaining the theory and escaping Forbes's conclusion already quoted, and that the course pursued by Kirchhoff in the original statement of his theory of the solar constitution,* namely, by assuming that the depth of the reversing atmosphere is not small compared to the radius of the sun. But innumerable observations during the score of years which have lapsed since that time prove that such a reversing atmosphere must be very thin. The famous observation of Professor Young during the total eclipse of 1870, when he saw appreciably all the Fraunhofer lines reversed, has naturally been received as the strongest confirmation of Kirchhoff's views as to the locus of the origin of the dark lines. But this very observation restricts the effective atmosphere (save for hydrogen and one or two other substances) to a depth of not more than 2″. Thus, singularly enough, the very observation, which led to the firmest belief among spectroscopists in the correctness of Kirchhoff's view, exposed at the same time its most vulnerable point.

Another theory of the solar constitution, that of Faye, assigns a different seat to the stratum producing the Fraunhofer lines, namely, the photosphere itself. Regarding the principal radiation of the sun as coming from solid or liquid particles floating in a gaseous medium, the cloud-like stratum thus formed is necessarily somewhat transparent. According to his views, these particles are the sources of the continuous spectrum, and the medium in which they float is the locus of the selective absorption.† Thus he attempts to reconcile the general theory of Kirchhoff with the observations and deductions of Forbes, which, as we have seen, were a constant stumbling block in the way of accepting Kirchhoff's explanation.

Lockyer seems to have accepted this theory, and to have defended it in the earlier portion of his work;‡ but in 1872 after Young's important observation of 1870 and its confirmation in 1871, he changed his views and regarded the layer just outside the photosphere as the true seat of the selective absorption producing the Fraunhofer lines.§ I supposed in 1873 that my observations then published could be explained on Faye's hypothesis.

* Untersuchungen über das Sonnenspectrum. Berlin, 1862, pp. 14–15.

† Comptes Rendus, vol. lx, 1865.

‡ See "A lecture delivered at the Royal Institution," May 28th, 1869. Quoted in Lockyer's Solar Physics, pp. 220–221; also "The Rede Lecture," May 24th, 1871. Quoted in Solar Physics, pp. 317–318.

§ See revised report of two lectures delivered at Newcastle-upon-Tyne in October, 1872, Solar Physics, p. 409.

There is, however, a fatal objection to the explanation as given by this theory. If the luminous particles are precipitated from the vapors of the photosphere, they cannot be at a higher temperature than the circumambient gases; on the contrary, on account of their greater radiating power they must be slightly cooler. But the fundamental theory of absorption demands a lower temperature for the vapor producing dark lines than that of the principal source of light behind it; consequently this view of Faye cannot be accepted without great modifications.

Before advancing any theory of my own, it may be well to emphasize two principles taught by the theory of absorption, to which all hypotheses must be conformable. That Faye's fails in this is sufficient cause for its rejection.

1st. To produce dark lines in a spectrum by absorption, the source of absorbed light *must* be at a higher temperature than that of the absorbing medium.

2d. There is an inferior limit of brightness below which the course of absorbed light cannot go without the spectral lines becoming bright.

Of these, the first is familiar and requires here neither proof nor comment; the second, though not less evident, is less familiar because less important. As we shall make use of it, however, it may be well to enforce it by reference to common experience. Were it not true it would be impossible to see bright lines in the spectrum of any flame to which daylight had access, for in this case the conditions demanded by the first principle are fully met, the sun being the origin of the daylight. That we do not see absorption lines is due then alone to the lack of necessary brilliancy in the daylight.

Thus much premised we can frame a theory which explains all the observed phenomena exhibited by the spectroscope, and is also rendered highly probable by the revelations of the telescope.

As is well known, the solar surface when examined with a powerful telescope of large aperture presents a granulated appearance, the granules in general subtending an angle of a fraction of a second only. Probably this appearance is better known to the majority of astromoners by means of Professor Langley's admirable drawings* rather than by personal observation. These granules I regard as marking the locus of currents directed generally from the center of the sun. About these currents are necessarily currents in an opposite direction which serve to maintain a general equilibrium in the distribution of mass. Let us consider the action of such an ascending current. Starting from a low level at a temperature which we may regard as

* This Jour., vol. vii, 1874, and vol. ix, 1875. Plates.

above the vaporizing point of all elements contained in it, as it rises to higher levels, it cools, partly by radiation, more by expansion, until finally the temperature falls to the boiling point of one or more of the substances present. Here such substances are precipitated in the form of a cloud of fine particles which are carried on suspended in the current. The change of state marked by the precipitation is accompanied by a sudden increase in radiating power; hence these particles rapidly lose a portion of their heat and become relatively dark, to remain so until they are returned to lower levels by the currents in a reverse direction.

In this theory it will be observed, there is nothing which does violence to our accepted notions of the solar constitution. Indeed, it differs chiefly from that of Faye in localizing the phenomena of precipitation, instead of regarding it as proper to all portions of the photosphere; and, what is quite as important, in supposing the precipitation confined to one or two elements only. I shall attempt to define these elements farther on.

In our theory, then, the granules are those portions of upward currents where precipitation is most active, while the darker portions, between these bodies, are where the cooler products of this change with accompanying vapors are sinking to lower levels.

Having stated the theory we will now apply it to the four classes of phenomena defined above.

From the nature of the condensation, the granules or cloudy masses must be very transparent, because the condensation is confined to elements which have very high boiling points, and because such elements can be but a portion, perhaps but a small portion, of the whole matter contained in the upward currents.

It is not *à priori* improbable that we receive light from many hundreds of miles below the general outer surface of the photosphere. Since these cloud-like sources of intenser radiations are surrounded on all sides by descending currents of colder vapors all the white light which comes to us must have passed through media capable of modifying it by selective absorption. Again, since at the center of the solar disk we can see as far into the photosphere as at the limb and practically no further, the phenomena of absorption ought to be on the whole, the same in both regions.

Thus the fundamental and most important class of phenomena above classified finds a simple and logical explanation.

With regard to the phenomena of class II, we have but to define the problem in order to find the solution at hand. All the lines of class II belong to vapors which lie high in the

solar atmosphere, as is evident from their frequent reversal in the chromosphere. On the center of the disk these lines are hazy or "winged," but not so at the limb. To the spectroscopist this aspect is characteristic of greater pressure, that is, of more frequent molecular impact. The observation then proves that the dark lines of hydrogen, magnesium, sodium, etc., as seen at the center of the solar disk are produced by the elements in question at a higher pressure than the corresponding lines at the limb. Accepting our theory this must be so; for, supposing the transparency of the photosphere is such that we can see into it a distance of 2000 miles, than at the center of the disk, we have light modified by selective absorption all the way from the extreme outer chromosphere down to 2000 miles below the upper level of the photosphere; while 10″ from the limb the light, though coming from the same depth of vapor measured along the line of vision has its lowest origin more then 1700 miles farther from the sun's center than in the previous case. Of course the numbers here used have no definite significance, but modify them as we will, within the bounds of probability, the reasoning remains the same.

Suppose now a certain vapor which is confined to the upper stratum of the photosphere, or rather, one of which the lower limit is thus restricted; then according to the reasoning of Forbes, the force of which has been shown, its absorption lines ought to be strongest at the limb. This is the condition which produces the phenomena of Class III.

Before discussing the final class we must recall a fact familiar to the most casual observer of the sun, namely, that lying upon the photosphere is a stratum producing a very strong general absorption, so strong indeed that the disk is probably less than a fourth as brilliant near the edge as at the center. This layer is *very thin*, as proved by the great difference in brilliancy between the upper and lower portions of faculæ. Since the difference of absorption at the two levels is very great, the conclusion follows because the facula itself is so low that it rarely, if ever, appears as a projection on the limb of the sun. For convenience let us call this layer A.

Imagine then, a stratum of vapors, B, above the layer just described, which are not represented at all in the photosphere, and which are of nearly the same temperature as this layer A.*

* This supposition is not opposed to probability, for though we must regard the temperature generally decreasing in passing from the photosphere outward, it does not follow that this decrease is continuous. A similar general law may be stated for our own atmosphere, but in a clear night the air in the immediate vicinity of the ground is colder than that just above. The explanation of this phenomenon is familiar in the theory of dew and hoar frost. Analogous causes for irregularity in the distribution of temperature in the solar atmosphere must be even more efficacious, since the layer A is probably a more vigorous radiator than the earth, and the gases above it are certainly far more diathermous than our atmosphere.

Then (for the sake of simplicity regarding this layer as having no selective absorption) suppose all beneath the two spherical shells in consideration to be removed. In the spectroscope, light from such a source as the two layers A and B would yield a continuous spectrum; for the inner shell (A), radiating only white light, would be robbed of nothing not supplied in equal quantity by radiation from the outer shell (B), since they are of the same temperature. If such layers as these really do exist about the sun, we can now readily state the appearances which would be presented by a sun so constituted, if the threefold system should be studied spectroscopically. In the center of the projected disk, the lines proper to the exterior shell (B) would be reversed, i. e. dark. As we approached the edge, however, *owing to the opacity of the inner shell*, the conditions would approximate to what they would be if the layers A and B existed alone, the central body being removed, and the lines would fade; if faint, they would vanish. This is our explanation of the phenomena of Class IV.

Every theory involves certain conditions. We finally judge of the soundness or unsoundness of any theory largely from the consideration of these implied conditions and of the extent to which they are fulfilled by it. For instance, our explanation of the fact that certain very fine lines are stronger at the center (IV) demands that the substances giving such lines should be found in the chromosphere, indeed, mainly restricted to the chromosphere. Fortunately I can say that one of them (6371) which I first discovered and measured carefully is identical with the 14th line of Young's second Catalogue of Chromosphere Lines. The other one, the wave length of which I took from Ångström's chart without correction, may correspond with Young's 9th (6429·9) line of the same catalogue, which differs in place by only one-sixth the distance between the D lines. This I shall test at the earliest opportunity.

If the theory I have proposed is correct, it affords the first definite evidence of the existence of *chemical compounds* in the sun, for in accordance with it the lines of Class III and Class IV belong to substances which are not found in the lower photosphere. We know, however, that all gases must increase in density in passing from their outer limit toward the center of the sun; and we have seen a proof of this in the case of hydrogen and certain other vapors in the discussion of our observations, which showed that the characteristic lines indicated greater density when they originated at greater depths. The only escape from the contradiction is in the assumption that the lines of the last two cases (III, IV) are due to compound vapors having a dissociation temperature below that of

the lower photosphere. Of course the substances of Class IV have a lower dissociation temperature than of Class III.

A naturally suggested and legitimate subject of speculation is as to the nature of the substance which, by precipitation, forms the cloud masses of the photosphere. We may predicate three properties with greater or less positiveness, viz:

1st. The substance has a boiling point above that of iron, for iron vapor at a lower temperature exists in its immediate neighborhood.

2d. The molecular weight is probably not great, for, though precipitated below the upper natural limit of its vapor, there are few elements found in abundance above it, and those in general of low vapor density.

3d. The element is not a rare one. Of these guides the last is of the least value.

The substances which apparently meet all these conditions are carbon and silicon; nor is it easy to name any other which will. Accepting for a moment as an hypothesis that the light coming from the sun is radiated by solid or liquid particles of carbon just at the point of vaporization let us see if the facts of observation fulfill the implied conditions.

As a first consequence, we see that the temperature and light of the photosphere are defined as those of solid carbon at the point of volatilization. In the electric arc there is a very small area of the positive carbon pole at this high temperature. Though this area is in a very disadvantageous position for observation, and can consequently have but a disproportionally small share in producing the total effect, the splendor of the electric light might almost tempt us to believe the guess a valid one. Another consequence implied, however, namely, that the spectral lines proper to simple carbon are absent in the solar spectrum, is doubtless better adapted as a crucial test of the hypothesis than a study of the electric light. There has been evidence recently offered that carbon lines are present in the solar spectrum. Granting this, we perceive that the photosphere contains solid or liquid particles hotter than carbon vapor, and consequently not carbon.

I am then inclined to suspect that the photospheric material may be silicon, which, though denser in the gaseous state than carbon, is not improbably more abundant. There is also good reason to suppose that carbon is precipitated at a higher level, and the analogous but less common element boron may add a minor effect.

In the explanations which I shall give of the remaining phenomena, it may serve to fix the ideas, to think of the granules which characterize the sun's photosphere as clouds of a substance like precipitated silicon. At any rate we are sure

that the substance in question, so far as we know it, has properties similar to those of the carbon group.

I have given plausible explanations of all the phenomena included specially in my own observations. It remains to discuss the others, briefly mentioned above.

The substance precipitated cools very rapidly, as it is an excellent radiator, separated from space only by extremely diathermous media. It forms then a smoke-like envelop, which ought to exert just such a general absorption as that observed at the limb of the sun. It is thin because of the relatively great density of the substance in the liquid or solid state; thus the apparent brilliancy of the faculæ is readily understood.

If there is any disturbing cause which would tend to direct currents of gas, over a considerable area of the solar surface, toward a point, this smoke, instead of quietly settling down to lower levels between the granules, would concentrate about this point, there exercising a marked general absorption which would betray itself as a spot. At this place the suspended particles would sink to lower levels with constantly increasing temperature, until finally, heated to intense incandescence, they would revolatilize. Thus the floor or substratum of every spot must be a portion, depressed it is true, of the photosphere. All the spectroscopic phenomena of spots, which have proved so perplexing, are thus naturally and easily explained.

In the immediate neighborhood of a spot, the centripetal currents bend down the ordinary convection or granule-producing currents, so that they are approximately level. Before, the latter cooled suddenly by rarefaction in their upward course, now they cool mainly by the much slower process of radiation; thus, while before the locus of precipitation was restricted, it is now greatly extended. This is the cause of the great elongation of the granules in the penumbra, a real elongation, I imagine, and not merely an apparent one.

Finally, concerning the close duplicity of certain lines, we may reason thus:—If we could surround the sun by a stratum of gas hotter than the photosphere and much rarer than that producing the corresponding Fraunhofer lines, we should, as is shown by a course of reasoning which I have given in another place,* see each dark line divided by a sharp bright line in its center, that is, doubled. But as a consequence of the theory, this supposed condition must be practically met in the case of certain vapors in the sun. The gases just over the granules, in the vertical currents, are at a very high temperature, essentially that of the condensing material itself, consequently much hotter and rarer than the relatively low-lying vapors which, as we have seen, produce the Fraunhofer lines.

* On Lockyer's Hypothesis, Am. Jour. Chem., vol. i, p. 15.

There are, however, certain evident limitations to these conditions; in other words, we cannot expect to see all the dark lines doubled by any increase of dispersive power. For instance, a line must have a marked tendency to broaden with increased pressure, otherwise the duplication cannot be pronounced. Again, the layer of rare vapor must be thin, or its temperature cannot be relatively high throughout, as demanded by the theory. This evident condition doubtless gives the reason why the hydrogen lines, though the broadest in the solar spectrum, are not sensibly double.

The theory of the constitution of the sun above proposed, may be briefly recapitulated thus:

Convection currents, directed generally from the center of the sun, start from a lower level where the temperature is probably above the vaporizing temperature of every substance. As these currents move upward they are cooled, mainly by expansion, until a certain element (probably of the carbon group), is precipitated. This precipitation, restricted from the nature of the action, forms the well-known granules. There is nothing which has come under my observation which would indicate a columnar form in these granules under ordinary circumstances.

The precipitated material rapidly cools, on account of its great radiating power, and forms a fog or smoke, which settles slowly through the spaces between the granules till revolatilized below. It is this smoke which produces the general absorption at the limb and the "rice grain" structure of the photosphere.

When any disturbance tends to increase a downward convection current, there is a rush of vapors at the outer surface of the photosphere toward this point. These horizontal currents, or winds, carry with them the cooled products of precipitation which, accumulating above, dissolve slowly below in sinking. This body of 'smoke' forms the solar spot.

The upward convection currents in the region of the spots are bent horizontally by the centripetal winds. Yielding their heat now by the relatively slow process of radiation, the loci of precipitation are much elongated, thus giving the region immediately surrounding a spot the characteristic radial structure of the penumbra.

This conception of the nature of the penumbra implies a ready interpretation of a remarkable phenomenon, amply attested by the most skillful observers, and, as far as my knowledge goes, wholly unexplained; namely, the brightening of the inner edge of the penumbra in every well-developed spot.*

* Relating to this phenomenon, see important observations by Professor Langley, this Journal, vol. ix (1875), p. 194; also Le Soleil, par Le P. A. Secchi, Paris, 1875, chap. IV, p. 80, and particularly fig. 46, p. 90, with explanatory text.

This interpretation is perhaps most readily imparted by a comparison of the hot convection currents in the two cases. When the convection current is rising vertically, the medium is cooled by expansion until the precipitation temperature is reached, when all the condensible material appears *suddenly*, save as it is somewhat retarded by the heat liberated in the act. Immediately afterward the particles become relatively dark by radiation. In the horizontal current a very different condition of things obtains. Here the medium does not cool dynamically by expansion, but only by radiation; hence, since the radiation of the solid particles is enormously greater than that of the supporting gas, practically by that of the particles themselves. Thus after the first particle appears, it must remain at its brightest incandescence until all the material of which it is composed is precipitated. From this we see that such a horizontal current must increase gradually in brilliancy to its maximum, and then suddenly diminish, an exact accordance with the facts as observed.

Johns Hopkins Univ., Baltimore, September, 1880.

ART. IV.—*Review of Professor Hall's recently published volume on the Devonian fossils of New York* (constituting Part II, vol. v, of his quarto series on the Paleontology of the State); by Dr. CH. BARROIS.*

THE State of New York has recently published the second part of vol. v, of the Paleontology of New York, by Professor James Hall. This volume of 492 pages and 120 plates, 4to, contains the descriptions of the Gasteropods, Pteropods and Cephalopods of the Devonian formation of this part of North America.

Before presenting to the readers of the Revue the scientific results acquired in this important work, it is proper to refer to the volumes which preceded it, and to speak of the immense charge which the State has confided to Professor Hall, a charge which has given to science the geology, and then the Paleontology, of New York.

The first researches of Professor Hall were made in the State of New York in 1837. He was appointed by the Government, with Mather, Vanuxem and Emmons, to collect the materials for a geological description of that region. During the years which followed, the annual reports of these savants

* This review appeared in the number of the Revue Scientifique (Paris) for September, 1880, and has been translated from the French for this Journal. The volume by Professor Hall bears the date December 15, 1879. Albany, New York. (Van Benthuysen & Sons.)

made known their progress and their discoveries; and in 1843, appeared in four quarto volumes the final reports on the Geology of the State. These geologists had divided the State into four districts; and in seven years they had succeeded in making a map of a hitherto unknown region as large as Ireland; they had besides given to their country a work which has since become the foundation of stratigraphical Geology in America.

The part described by Professor Hall was the western portion of the State, that is to say, the portion where the non-metamorphic beds were filled with fossils; thus he found himself prepared to undertake the publication of the Paleontology of the State of New York with which he was officially charged in 1843. This work has become the great work to which Mr. Hall has devoted all his talents and all his energy. Under this modest title, it is not only the description of the fossils found in the formations of the State of New York, which the author would make known to the learned world; he conceived the grand project, now almost entirely accomplished, to illustrate the fauna of all the Paleozoic formations of the United States. This labor necessitated considerable preliminary research. It was necessary first to traverse the Appalachian range from Canada to Alabama, from the ocean to the plains of the Mississippi River, that is to say, an extent of country equal to half of Europe, to observe the order of succession in the strata, their parallelism, their continuity, or their interruptions, and to collect the fossils for future descriptions. These long and toilsome journeys, many of them in regions now civilized but then uninhabited or wild, were made without any official aid. The results have been great.

In 1847 was published vol. i of the Paleontology of New York, a volume of 340 pages and 90 plates. With this commenced the series of Mr. Hall's paleontological publications; a series which has been going on uninterruptedly to the present time; which, besides the eight quarto volumes (certain of them being in two parts) of the Paleontology of the State, include also many memoirs in the octavo Annual Reports of the State Museum of Natural History. Volume i of the Paleontology is devoted to the description of the fauna of the Lower Silurian; volume ii, to the fauna of the Middle Silurian, illustrated by 85 plates; volume iii (two volumes) treats of the Upper Silurian, and contains 120 plates; volume iv contains the descriptions of the Brachiopods of the Devonian formations, with 63 plates; a sixth volume, which is outside of the series, has 137 photographed plates of Devonian fossils. Of the series, the sixth and seventh volumes which have just appeared, constitute part 2 of volume v. The first part, devoted to the Devonian Lamellibranchs will next appear.

In this work, the Devonian fauna of the State of New York is divided as below, in the descending order.

Catskill Group.
Chemung "
Portage "
Hamilton " { Genesee slates. / Hamilton beds. / Marcellus shales.
Upper Helderberg Group. { Upper Helderberg limestone. / Schoharie Grit—(Calcareous sandstone). / Cauda-galli grit.

This group of formations is mostly limestone at the base, while slates and sandstones prevail in the upper part. To the Cauda-galli grit and the Catskill group we shall not have occasion to refer, as these divisions do not contain representatives of the forms treated of in this volume. The Schoharie species are imperfectly preserved; those of the Upper Helderberg limestone and the Hamilton group are in good condition; those of the Portage and Chemung are less perfect. We will examine successively these different groups, and endeavor to give an idea of the fauna of Gasteropods, Pteropods and Cephalopods which have been described in this work.

GASTEROPODS.—The Platyceras* of the family of the Capulides, form the most striking feature of the Helderberg limestone; they occur there in great abundance and in an astonishing variety of forms (twenty-three species). The great variations in form and character of the Platyceridæ render their determination very difficult, and there are always specimens which cannot be classified; they are found passing from one form to another, and there are species which perhaps should be united. The Platyostoma form another group of Capulides, comprising fourteen species, among which there are several which pass into the preceding genus. Two species taken from the genus Platyostoma are the types of the new genus Strophostylus of Mr. Hall. The Capulides have not attained in Europe the same development as in America; but it is nevertheless at the same epoch that they appear in the greatest abundance. In Germany the Platyceras and the Platyostoma characterize the "Hercynien" limestone of Kayser, but disappear in the Spirifera sandstone. In the west of France they abound in the "Hercynien" limestones of Erbray and also in the Devonian limestones of Courtoisières, etc., while they are wanting in the synchronous graywackes of Ardennes and of Bretagne. These forms are species of calcareous formations rather than characteristic of the Hercynien epoch; one cannot distinguish the living Capulus from the Devonian Platyceras, and many

* The French of Dr. Barrois is here literally followed in making the name of a genus a noun of multitude.

authors unite these genera. The *Platyceras pyramidatum* (Hall) resembles the *P. hercynicus* (Kayser), the *P. symmetricus* (Hall) the *P. uncinatus* (A. Roemer), and the *P. carinatum* (Hall) the *P. zinkeni* (A. Roemer).

It does not appear that there are identical forms common to the Devonian strata of America and Europe; but if it be impossible to assimilate the species of the two sides of the Atlantic, we should nevertheless have a false idea of these faunas by neglecting all comparison. The American Devonian species have representatives in the same formation in Europe; they are analogous forms, and perhaps geographical varieties. This important fact is observed: that the change in genera and families has been in a great degree the same in the Devonian series of the two continents. Thus the Macrocheilus (Phill.), represented by four species in the Devonian of New York, are Devonian forms common in Europe. It is the same with the Loxonema (nineteen Devonian species in America); the Euomphalus (nine American species); the Pleurotomaria (twenty-four species); the Murchisonia (six species); the Bellerophon (twenty-four species); and the Turbo (one species).

The American *Loxonema Hamiltoniæ* (Hall) resembles the *L. nexilis* (Phill.) of England; the *Euomphalus Decewi* (Hall) the *E. Wahlenbergii* (Goldf.); the *E. clymenoides* (H.) the *E. planorbis* (Goldf.); the *Pleurotomaria lucina* (H.) the *P. rotundata* (Münst.); *P. ella* (Hall) the *P. radula* (Kon.); *P. filitexta* (H.) the *P. clathrata* (Münst.); *P. trilix* (H.) *P. quadrilineata* (Sandb.); *P. quadrilix* (Hall) the *P. lenticularis* (Goldf.); *Murchisonia desiderata* (Hall) *Murchisonia angulata* (de Vern.); *M. micula* (Hall) *M. bilineata* (Goldf.); *M. maia* (Hall) *M. trilineata* (Sandb.); *Bellerophon curvilineatus* (Hall) *B. dubia* (d'Orb.); *B. acutilira* (Hall) *B. Murchisonia* (d'Orb.); *B. brevilineatus* (Hall) *B. Verneuili* (d'Orb.); *B. natator* (Hall) *B. expansus* (Sow.); *B. leda* (Hall) *B. decussatus* (Flem.); *B. Helena* (Hall) *B. hiulcus* (Mart.); *B. rotalinia* (Hall) *B. trilobatus* (Sow.); *B. mœra* (Hall) *B. tuberculatus* (d'Orb.); *Porcellia Hertzeri* (Hall) *Porcellia puzo* of Europe.

There are therefore relations between the Devonian faunas of the two continents. It is to be noticed also that the genus Euomphalus is divided, in the Paleontology of New York, into two sections, having for types the European Straparollus of Montfort and the Phanerotinus of Sowerby; Professor Hall takes from this family the *Euomphalus Decewi* (analogous to our *E. Wahlenbergii* (Goldf.) to make the type of his new genus Pleuronotus. The Bellerophons are as abundant in the Devonian in America as in Europe; there are five species in the Upper Helderberg, fourteen in the Hamilton, and five in the

Chemung. It is interesting to note the complete absence of the allied genus Bucania, which, on the contrary, is so widely distributed in the Silurian of this region.

There are, however, certain genera of Gasteropoda, which appear peculiar to the Devonian formation of America. Such are the Cyrtolites of Conrad (two species), and the Cyclonema (six species)—a new genus of Mr. Hall analogous to Pleurotomaria. The Callonema, another new genus (three species) in which Mr. Hall places certain Isonema, Pleurotomaria, Loxonema had perhaps an analogue in Europe in the *Natica subpiligera* (Le Hon) of the Devonian of Belgium. The same may be said of his new group Palæotrochus (one species), the casts of which resemble the *Pleurotomaria Griffithii* of MacCoy.

Pteropods.—Little has hitherto been known of the Paleozoic Pteropods of America; they had however acquired a great development in the Devonian era, for Mr. Hall has described thirty-two new forms, distributed in seven different genera.

The Tentaculites which are represented in the Silurian Clinton Group of New York, and in the more ancient Trenton group in a neighboring State, have considerable differences from the forms which are found in the Upper Silurian and Devonian formations. Mr. Hall is led to consider these differences as generic; and he limits the genus Tentaculites to forms which are conical, straight, elongated and covered with rings; this genus thus defined first appeared in the Upper Silurian, and is represented by six species in the Devonian. The species of Tentaculites cited from the Lower Silurian appertain to the genus Cornulites, which attained its greatest development at this ancient period, and became extinct at the epoch of the Niagara. The Tentaculites of the American Devonian have relations with the European forms of the same epoch; thus we may compare *T. attenuatus* (Hall) of America with the *T. tenuis* (Sow.) of England; *T. scalariformis* (Hall) with *T. scalaris* (Schlt.).

The genus Styliola is represented in America by two species, one of which presents four varieties; this species, *Styliola fissurella*, is very analogous to *S. clavulus* (Barr.); it has a wide geographical extent in the United States, where it is recognized over an area of 700 miles. It appeared upon this continent as in Europe after the genus Tentaculites; in Europe it appears in the Third Fauna; in America it is limited to the Devonian.

The genus Coleoprion of Sandberger is represented by a doubtful form from the Hamilton group. Professor Hall has designated the genus Coleolus for six forms, of which the type *C. tenuicinctum* had been hitherto connected with the Coleoprion; these are tubular, conical forms, elongated, usually

straight, and with thick shell; they are ornamented with striæ or with oblique rings. This genus is limited to the Devonian formation.

The Hyoliths are distinguished from all the other genera of American Pteropods by their geological extent; they appear in the Cambrian (Potsdam) and are found above the Devonian and in the Carboniferous limestone. It is remarkable to see this genus diminish in the Middle Silurian and even disappear in the Upper Silurian, which is so rich in fossils and in other Pteropods, then reappear with six new forms in the Devonian. On the contrary, it is in the second and third Silurian faunas that this genus attains its full development in Europe. There are nevertheless resemblances between the forms of the two continents: the *Hyolithes aclis* (Hall) of the Hamilton, resembles the *Hyolithes discors* of Barrande; the *H. striatus* (Hall) the *H. solitarius* (Barr.); the *H. singulis* (Hall) the *H. striatulus* (Barr.).

There is no room to remark on the new genus Clathrocœlia, established on two imperfectly preserved specimens from the Hamilton group. On the contrary, the European genus Conularia is represented by ten beautiful new species in the Devonian of America. They differ from those which had been previously described from the Silurian of the same region, of which Mr. Hall had already described seventeen specific forms of the second fauna; they differ also from the seven forms which have been recognized in the Carboniferous limestone.

CEPHALOPODS.—Mr. Hall admits entirely, for this part of his work, the generic divisions which have been established with so much talent by our illustrious compatriot M. Barrande. The American Orthoceras compared with those of Europe, and especially with those of Bohemia, present some interesting facts. The ornaments of the shell are in Bohemia generally imbricated lamellose striæ; in America they are reticulated. The curved forms common in Bohemia are rare in America; the Brevicorns of M. Barrande are scarcely represented in America. Among the curved forms there are more relations between the American and Bohemian forms.

The genus Orthoceras appeared in America in the Cambrian (Calciferous sandstone); the sub-genus Endoceras did not pass beyond the second fauna; the Orthoceras proper are found as far as the Permian. There are two principal horizons of Orthoceras in the Devonian formation; the Schoharie grit, which is richest in species and individuals, has only ten meters of thickness, and the Hamilton group, 400 meters thick in the eastern part of the State of New York, is reduced to 100 meters in the western part. The Schoharie grit passes insensibly into the Upper Helderberg limestone, and it is

curious to see the fauna of the Cephalopods diminish in proportion as the rock becomes more calcareous. The Orthoceras are distributed in the Devonian formation as follows:

Upper Helderberg group, including the Schoharie grit	30
Hamilton group	29
Portage "	4
Chemung "	19
Waverly "	7

The numerous and varied forms of the Schoharie grit are usually imperfect; they occur in a coarse sediment and are generally in the condition of casts of the interior. Five of these forms are found in the Upper Helderberg limestone; while other species are proper to this horizon, and two of the lower rock are continued into the Hamilton group. There are few Orthoceratites in the Hamilton in the eastern part of the State, where it is shaly, but they are more numerous toward the center of the State, where the sediments are charged with lime. It is interesting to note that the Nautilus have not had the same recurrence; and they are found in the more eastern arenaceous beds of the group. The Portage group has its own proper fauna of Orthoceras, and has few characters in common with the neighboring groups. The Orthoceras of the Chemung group present the singular trait of being intermediate in general form between those of the Upper Helderberg group and those of the Hamilton.

The Bactrites have been but sparingly found in the United States; only a single species is known in the Marcellus shales. The Gomphoceras have nearly the same extent as the Orthoceras, but they are most numerous in the limestones of the Upper Helderberg in the western part of the State. The species in the Schoharie grit are generally small, but there are large ventricose forms in the limestone of the Upper Helderberg; those from the Hamilton to the Chemung are characterized by a large proportion of short, ovoid forms, and by some which are larger and fusiform. The American species, compared with those of Bohemia, differ from these generally in the form of the mouth, it having often two openings, united by a canal, in the Bohemian species, while in the American species the openings are near together and become a single one of trilobate form. The Schoharie grit has furnished six species of Gomphoceras, the Upper Helderberg six, the Hamilton eleven, the Portage one, and the Chemung two: still it is impossible to state exactly the Cephalopod fauna, of this last epoch, for it has furnished a great number of fragments of species which cannot be determined.

The existence of Cyrtoceras in America was first recognized by Conrad in 1838, but it is difficult to define its limits, and it

comprises at present, according to Mr. Hall, many species which should be removed from the genus. The Gyroceras, which are Cyrtoceras with volutions more enrolled and separated, present so many relations, in the position of the siphon and the ornamentation, with the American Cyrtoceras, that one cannot really consider them as distinct generic types; but that they may be reunited. Thus the series of *Cyrtoceras alternatum, eugenium, citum*, is parallel with the series *Gyroceras Nereus, trivolve, laciniosum, Matheri, paucinodum, undulatum;* we follow all the changes in the two series from a like initial form to a shell several times enrolled. A second group, comprising more massive forms, shows the same relations between the series of the *Cyrtoceras Jason* and the *Gyroceras cyclops.* The generic distinction of all these forms, based upon the degree of curvature of the shells, is entirely artificial, and neglects the essential characters which unite all these shells in the same group. If it is easy to recognize a Cyrtoceras in the Silurian period, it becomes more and more difficult to do it with precision in the Devonian, in proportion as the Gyroceras become developed. The general law is nevertheless that the Gyroceras succeed the Cyrtoceras in time. These forms are represented by six species in the Schoharie grit, twelve in the Upper Helderberg, six in the Hamilton and one in the Chemung.

The genus Trochoceras, established by MM. Hall and Barrande for the Gyroceras enrolled in helix form, is essentially Silurian in America as in Europe. It has attained its greatest development in America at the epoch of the Niagara. M. Barrande has described forty-five species in the Silurian of Bohemia. In the Devonian of America, this genus is limited to the Schoharie grit; it is there represented by nine different species; they appear to hold here the place of Nautilus, which have entirely disappeared, and which on the contrary replace them in the period of the Hamilton.

In the Devonian, the Nautilus are abundant, in place of the Orthoceras which we have seen so predominant in the Silurian; in the Devonian, Gyroceras are developed to the detriment of the Silurian Cyrtoceras; but it is only at the middle of the Devonian period that the fauna of the Nautilus is greatly developed; there are ten species in the Hamilton; all presenting a remarkable unity in the plan of their ornamentation. The subgenus Discites of McCoy should include three Nautilus of America, two of the Upper Helderberg and one of the Hamilton; these differ from the Nautilus proper in the angular form of the shell, the position of the siphon, and the character of ornamentation.

The Goniatites, with the exception of *G. mithrax* found perhaps in the Upper Helderberg of Ohio, first appeared in

the beds of the Hamilton. They occur there in abundance; they present a remarkable variety of form (seven species), and the type attains its greatest dimensions in the Hamilton. Their appearance characterizes an epoch which differs much in all its fauna from the preceding. They continue quite abundant during the following periods. There are seven species in the Portage, five in the Chemung.

All the forms which we have passed in review are figured in a style which does great credit to the draughtsmen of Mr. Hall, Messrs. G. B. Simpson and H. M. Martin. The fifth volume of the Paleontology of New York, of which we have endeavored to give some idea to the readers of the Revue, is then essentially a work of paleontological specification. But it contains besides important geological observations: such are the examinations made by Mr. Hall in the vicinity of Louisville, Kentucky, to determine the age of some fossils found near the Falls of the Ohio.

This volume is destined, like the greater part of those preceding it by the same author, to make an epoch in science; for notwithstanding the labors of Rœmer, Sandberger, Kayser and Gessler, upon the Devonian formation, we have not such complete descriptions of the fauna of this period as have now been given in America by Professor Hall. Thus the Paleontology of New York will always occupy an honorable place among the publications of official geological surveys.

ART. V.—*Earthquake at the Philippine Islands, of July*, 1880. (Plate IV.)

THE earthquake of July, 1880, at Luzon, the largest of the Philippine Islands, was one of the most destructive on record. The shocks continued, with greater or less interruption, from the 14th to the 25th of the month, destroying churches and other buildings, and producing some loss of life. Records of the occurrences at Manila, and the other disturbed regions, and of the observations made with seismometers during the eventful period, were published from day to day in the "Diario de Manila;" and these records have since been collected into a small volume, bearing the title, "Los Terremotos en Filipinas en Julio de 1880."* From this volume we translate the following account of the seismometrical observations made—as

* Published at Manila, in a duodecimo of 152 pages. (Establecimiento Tipographico de Ramirez y Giraudier à cargo de C. Miralles, Magallanes, 3.) For the use of the copy of this volume which has supplied the facts here given, this Journal is indebted to Professor E. C. Pickering, Director of the Harvard College Observatory.

the Preface says—by "los illustrados PP. Jesuitas del Observatorio Municipal, á quienes nunca se agradeceran bastante los servicios prestados al pais en situacion tan angustiosa." The provinces of Manila, Cavite, Bulacan, La Laguna, Pampanga, and Nueva Ecija, were the chief victims from the terrible convulsions; and, in many parts, their "solid edifices were converted into shapeless heaps of ruins, and the materials of their prosperity buried beneath the rubbish."

Seismometric observations made at Manila, at the Observatory of the "Ateneo Municipal," from the 14th to the 25th of July, 1880.

The figures which accompany this Report (see Plate IV) are the records of the seismometer during the principal shocks of the earthquake. They were traced by a pendulum six meters long, suspended from a point at the termination of four metallic rods, and placed within a glass case. The pendulum could oscillate freely in all directions, not only under the impulse of violent shocks, but also of the slow and gentle undulations caused by movements in the walls of the building—to which it was rigidly attached. It oscillated over a spherical concavity made in a thick piece of wood, whose radius of curvature was equal to the length of the pendulum. The concave surface was sprinkled lightly with lycopodium powder, to receive the tracings made by the pendulum in its various movements. At the center of the concavity there was a small ring which was dragged by the pendulum in its first impulse, and which was left at a spot opposite to that from which the first seismic wave came. This apparatus is that called the *horizontal seismometer*.

The *vertical* seismometer used consists of a rigid metal rod, having a brass wire in the form of a spiral spring soldered to its upper end. To the last turn of the spiral is attached a cylindrical piece of lead, placed transversely to the rod, and at such a distance from it as would allow of its moving freely under any oscillations. Below the piece of lead is a small index of cork, also transverse to the rod, which is dragged on by the lead in any movements, and stops always at the point of maximum vertical oscillation.

The object of these instruments is, *first*, to determine the direction of the first horizontal undulation, and this is done by means of the ring at the end of the pendulum, which is pushed before it on the first impulse; *secondly*, to find out the general direction of the horizontal undulations, and their amplitude, by means of the lines traced by the same pendulum in the lycopodium powder; *thirdly*, to ascertain the greatest amplitude of the maximum vertical undulation by means of the index of the vertical seismometer; *fourthly*, to obtain, by the combination of

these two elements, the magnitude and direction of the oblique undulations.

From the indications of these two instruments the following results were obtained, during the successive days of the great earthquake. We do not attach to them an absolute value, since the seismometers cannot make perfectly correct observations, when such movements are of great violence and complication. Yet we believe that they afford quite a good registration of the phenomena, and will be useful for comparison with those of other earthquakes. The facts obtained are as follows.

The vibrations began during the months of April and May, in the northern provinces of Luzon. The center of oscillation, as indicated by the directions registered at Manila, appears to coincide with a volcano, which has been long extinct, situated between Lepanto and Abra, in the central Cordillera of Luzon, in latitude 16° 22′ N., and longitude 127° E. from the Spanish Observatory of San Fernando. At first the movements were weak and little frequent; yet in the month of June they became quite intense, and extended from *north to south* over a large zone. This direction never changed; and the few discordances recorded appear to have been a result of haste or want of care in the method of taking the observations, exactness being hardly attainable without special instruments for the purpose.

Early in July some vibrations were felt; yet from the 5th to the 14th none were recorded at Manila for any point on the island.

On the 14th, at 12^h 53′ P. M., when a storm from the northeast of Luzon was threatened, as indicated by an extraordinary fall of the barometer, the first shock occurred in which it was observed that there were two centers of oscillation (see figure 1); one in the second quadrant from the point where the oscillation of the pendulum of the horizontal seismometer commenced, and the other in the third, in which the oscillation of this first movement—mainly horizontal in direction—ended. The total amplitude of the oscillation reached 5° 25′. The horizontal pendulum left inscribed a cross whose arms intersected at a right angle, the first set, from S. 55° E. to N. 55° W., and the other, from S. 40° W. to N. 40° E.

The first impulse was in the direction from S.E. to N.W., and the amplitude of the oscillation in this direction covered an arc of 5° 25′, all apparently a result of the first shock; then the pendulum was violently oscillated in a direction perpendicular to this, and with an amplitude a little less than in the former case. The index of the vertical seismometer was moved 4^{mm} from its position.

After this first movement there were two more shocks at the end of an hour and a half. On the 15th and 16th no perceptible shocks occurred; and on the 17th, only two small shocks.

On the 18th, at 12^h 40′ P. M., occurred the great shock—one of oscillation and also of "trepidation," and spoken of commonly at the time as one of rotation. Its duration was 70 seconds. The movements of the pendulum were so many and various that it is not possible to indicate them all, and we limit our descriptions to the principal directions and the amplitudes of the same. For the rest the reader may refer to fig. 2. It may however be stated that, in our opinion, only the great oscillation from E. to W., which was the most regular and without violent shocks, corresponds to the actual inclinations of the disturbed buildings toward the west.

1. Maximum oscillation, from S. 85° E. to N. 85° W. (*b b′*, the direction of most intense oscillation); amplitude of the greatest oscillation in this direction 22°—or 11°, E. and 11°, W.

2. Maximum oscillation, from S.W. to N.E. true; amplitude 19°, but 10° 10′ to the S.W., and 8° 50′ to the N.E.

3. Maximum oscillation, from N. 4° W. to S. 4° E.; amplitude 16°, but 9° N. and only 7° S., whence it appears that the impulse was from the north to the south. The index of the vertical seismometer was moved 34^{mm} from its position.

From this time there was an uninterrupted series of small shocks, until the 20th at 3^h 40′ P. M., and then occurred a repetition of extraordinary violence, though only movements of oscillation and trembling ("trepidation)" occurred. Its duration was 45 seconds. The direction of oscillation was from S. 60° E. to N. 60° W.; the amplitude 12° 30′, but with the following peculiarities: there was no one total oscillation, but three semi-oscillations, indicative of the great violence of the shocks, (see, in fig. 3, the lines *a a′*, *b b′*, *c c′*); the pendulum, at the first impulse from S.E. to N.W., reached the height indicated by the line *a a′*; on returning to its point of departure, it received a new impulse which not only destroyed the velocity that it had acquired in its descent, but forced it to go a second and third time to the same height that it had reached after the first impulse. The vertical pendulum was moved 24^{mm}. The direction SS (see figure) was one of intense oscillation.

The pendulum continued oscillating during all the evening in a N.E. and S.W. direction. At 10^h 40′ P. M., occurred a second violent repetition, which lasted 55 seconds; and this shock had its peculiarities. In the preceding, the focus of most intense seismic radiation was in the second quadrant; in *this*, it began in the E. true, yet with much less intensity than before; and the focus before observed in the first quadrant continued to operate but with greater violence. In figure 4, we observe

that the oscillation from E. to W., true, had an amplitude of 10°—5° to the E. and 5° to the W., but that in the direction from N.E. to S.W. the amplitude was 17°, 9° to the S.W. and 8° to the N.E. *a a'*, *b b'*, *c c'* are directions of the first, second and third intense oscillations. In the vertical seismomenter the index moved 28^{mm}.

Vibrations continued; yet there was a marked diminution in frequency and intensity. The pendulum, which had not been quiet since the 18th until 3 P. M. of the 21st, was motionless for long intervals in the three following days. On the 25th, at $4^h\ 2'$ A. M., another shock was felt; it was of feeble intensity, yet of interest since the record bears evidence as to the gradual change in the center of seismic radiation which had been in progress. The direction of the undulation (fig. 5) was N. 64° E. to S. 64° W.; the amplitude of the oscillation was only 3° 54'. No vertical movement was appreciable, the vertical seismometer indicating a change of only $0{\cdot}7^{mm}$ from the normal position.

After this exposition of the results, we will recapitulate briefly the points established by the tracings on the lycopodium powder as shown in the figures

(1.) In the registration of the 14th (as represented in fig. 1), two radial centers are shown; the first in the second quadrant, from the point at which the movement began, and the second in the first quadrant where it ended.—(2.) In that of the 18th, also, we find the same two centers, but, besides these, other new ones, the pendulum moving in all imaginable directions. (See fig. 2.)—(3.) In that of 3 P. M. of the 20th (fig. 3), the focus of the second quadrant worked with wonderful violence, and the others had disappeared.—(4.) In that of $10^h\ 40'$ P. M. of the 20th (see fig. 4), a very great variation in the seismic foci is shown: the oscillations from E. to W., which correspond to the foci that before operated with so great violence, were gradual and of much less intensity, while, on the contrary, those from N.E. to S.W. indicate powerful undulations between these points. —(5.) Finally, in that representing the last oscillation on the morning of the 25th (see fig. 5), there is manifested only the one seismic focus of the first quadrant, and this of slight intensity, the others having wholly disappeared. In each of the figures the small circular dot one side of the center shows the position of the ring given by the first impulse.

We will not now offer any deductions from the facts observed, desiring only to place them before those versed in these subjects that they may themselves study them without prejudice from our opinions.

NOTE 1.—It should be understood that when we speak of the movement of the pendulum from one side to the other of the

center of reference, we do not intend to say that the buildings swayed equally with the pendulum, for, as is clear, the motion in one of the semi-undulations is not an effect of the impulse or inclination of the edifice, but of the velocity acquired in the first semi-oscillation. The divergences of the pendulum on each side from the center of reference have been indicated because this fact bears on the question whether the seismic waves resemble sound-waves in the air, or whether they are rather the effect of upward or downward movements in the earth at points more or less distant from the place of observation.

NOTE 2.—The figures have many lines that do not combine regularly with the rest. This has resulted from the shocks in a vertical direction, causing the pendulum to leap in a violent way and forcing it sometimes to abandon one curve in order to follow another started by the new impulse.

In conclusion, we assure our readers that the curves as presented in the figures were transferred from the lycopodium powder with the greatest possible fidelity.

These figures have been copied for this Journal by photography, in order that they might be a correct transfer from the original plate. Figures 1 and 5 are of the same size as on the original plates; 2, 3, 4, have been reduced one-half.—EDS.

ART. VI.—*Papers on Thermometry from the Winchester Observatory of Yale College;* by LEONARD WALDO.

I.—*On the Errors of the Kew Standards,* 578, 584 and 585.

IN order to avoid, as far as possible, any uncertainty as to what constitutes the mercurial standard thermometer to which the instruments sent here are referred, the following definition of this standard has been adopted and is printed upon the certificates of examination issued with standard thermometers sent here to be verified.*

"The theoretical mercurial standard thermometer to which this instrument has been referred, is graduated by equal volumes upon a glass stem of the same dimensions and chemical constitution as the Kew standards 578 and 584. The permanent freezing point is determined by an exposure of not less than 48 hours to melting ice, supposing the temperature of the standard has not been greater than 25° C. = 77° F. during the preceding six months. The boiling point is determined from the temperature of the steam of pure water at a barometric pressure of 760^{mm} = 29·9215 in. (reduced to 0° C.) at the level of the sea and in the latitude of 45°."

* The Kew thermometers are supposed to have their boiling points as nearly as practicable at 212° F. = 100° C. at the temperature of steam under Laplace's standard atmospheric pressure, or the atmospheric pressure corresponding to the following number of inches in the barometric reading, reduced to 32° F.,

$$29{\cdot}9218 + 0{\cdot}0766 \cos 2\phi + 0{\cdot}00000179\ H,$$

Where ϕ = the latitude and H is the height in feet above the sea level.—Rep. Br. Ass. Adv. Sci., 1854, p. xxxii.

We have not yet received from the Kew Observatory any further statement as to what the chemical constitution of the glass used in "Kew 578" and "Kew 584" is, than that they are blown from "Powell's best flint glass." This does not enter into the subject of our present paper and will be discussed in a subsequent one in connection with the comparison of the Kew standards with the standard thermometers of the Kaiserliche Normal-Eichungs-Kommission.

The thermometers, Kew 578 and Kew 584, are almost exactly alike with the exception of their graduations. Kew 585 is so much longer and of so much larger tubing, that it was not thought wise to include it in the standard to be established between 0° and 100° C. The following is the description of these instruments.

Designation.	How Graduated.	Length of 1°.	Smallest Graduation.	Tube. Length.	Tube. Diameter.
Kew 578	− 9° to + 105° C.	3·46 mm	0°·5	455 mm	6·0 mm
Kew 584	+ 14° to + 220° F.	1·87 "	1	455	6·1 "
Kew 585	− 34° to + 275° C.	1·73 "	1	618	7·4 "

Designation.	Cylindrical Bulb. Length.	Cylindrical Bulb. Diameter.	Remarks.
Kew 578	23 mm	6·0 mm	Graduated at the Kew Observatory, Jan., 1880. Filled in July, 1874.
Kew 584	23 "	5·5 "	Graduated at the Kew Observatory, May, 1880. Filled in July, 1874.
Kew 585	27 "	6·2 "	Graduated at the Kew Observatory, May, 1880. Filled in July, 1874.

They are each provided with a chamber at the upper end for the purpose of calibration. The measured bulbs of similar thermometers broken at Kew, give, approximately, a thickness of the walls of the bulb of 0·025 inch. With similar thermometers the average maximum depression of the freezing point observed after the boiling point, is found to be 0°·17 C.

The following pieces of apparatus were used in the investigation, and they will be referred to by the Roman numeral.

I. The Crouch microscope comparator, elsewhere described,* provided with an eye-piece micrometer by Powell & Leland, and an objective of 1 inch equivalent focus.

II. A pair of microscopes provided with eye-piece micrometers and objectives of 4 inches equivalent foci, by Beck. These microscopes can be adjusted so that their stages are in the same

* Proc. Am. Acad. Arts and Sci., Bost., vol. xiii, 1877–78, p. 352.

plane, and can be placed at varying distances from each other in order to bring the two ends of the column of mercury used in calibration into view at the same time.

III. A small vertical cathetometer by Wm. Grunow, graduated upon its vertical triangular bar to single millimeters and read by a vernier directly to $0{\cdot}2^{mm}$; $0{\cdot}05^{mm}$ can be readily estimated. The graduation extends over 220^{mm}. The telescope is provided with an objective of 4 inches focal length by Beck and an eye-piece micrometer by Rogers. The smallest division of the eye-piece micrometer subtends an apparent angle of 39 minutes, and the telescope magnifies 20 diameters at the distance at which it is commonly used. The vertical motion of the telescope is by means of a rack and pinion.

IV. The standard barometer, "Jas. Green, N. Y., 957." The mercury column in this instrument has a diameter of 0·50 inches nearly, and the glass tube has an exterior diameter of 0·63 inches. The exterior diameter of the glass cistern at its base is 1·60 inches. The vernier reads by estimation to 0·001 inches, and the scale is set about 0·01 inches lower than the measured height above the ivory point which is adjusted on Fortin's principal at the base, in order to correct for capillarity of the tube. The length of the brass tube is expressed in terms of the standard United States Coast Survey yard, to within any errors appreciable in its readings. It read within 0·001 inch of the standard barometer kept by Mr. Green as representing the standard of the Kew Observatory, in October of this year. After comparison it was carefully transferred to New Haven by hand, and since that date has been hung at the level of the boiling-point apparatus to be described. The attached thermometer has a correction of $-0°{\cdot}2$ at the freezing-point, and of $-0°{\cdot}7$ at 80° F. The barometer from the cistern upward is wrapped in cotton-wool to keep the temperature as constant as possible and to insure an accurate determination of it by means of the attached thermometer.

V. The freezing point apparatus, which consists of a tinned iron vessel within another, the space between them filled with cotton wool. The inner vessel holds two liters of melting snow or ice. There is provision for the escape of the water into a space at the bottom of the inner vessel, protected from radiation.

VI. A boiling-point apparatus constructed of brass after Regnault's plan. The diameter of the inner steam chamber is 13^{cm}, and the apparatus is provided with a water manometer to keep the pressure constant.

VII. A boiling-point apparatus, constructed entirely of glass, with a single steam chamber extending to a height of 71^{cm} above the surface of the boiling water. A water manometer

has its connection at the level of the thermometer bulbs, and a small thermometer is inserted at the top of the steam chamber to assure the observer that the temperature at the top is at 100° C. The escape of the steam is through a small vent at the top of the tube, and the amount of its opening is controlled by a small brass plate.

The details of the calibration of the Kew thermometers have been furnished us by the courtesy of Mr. Whipple; it has been so carefully done that it seemed necessary only to rigorously examine the thermometer at long intervals, for errors depending on this cause. The results of our calibration are given in the following table. The observations were made with apparatus II, and special care was taken to guard against any changes of temperature. The reduced results are as follows, where each line is the mean of three observations:—

Thermometer	Date.	Extreme readings.	Computed length of column.	Correction for calibration error.	Remarks.
	1880				
Kew 578	Oct. 15	−1°·1 +33°·6	32°·487	At 32°C. = +0°·007	The observations were all
		+31·0 +65·1	32·507	65°C. = −0·014	made by daylight and at one
		+63·7 +98·6	32·487	99°C. = +0·007	sitting for each thermometer.
					The extreme variations of
Kew 584	Oct. 15	+32·2 +82·3	49·040	79°F. = +0·021	the temperature of the room
		+76·1 +127·3	49·068	123°F. = −0·006	during the observations, as
		+119·1 +170·1	49·078	166°F. = −0·016	measured by two thermom-
		+162·2 +213·2	49·060	212°F. = +0·001	eters, one at each end of the
					tube being measured, was as
Kew 585	Oct. 15	−1·0 +50·9	49·813	50°C. = +0·015	follows:
		+49·0 +100·9	49·843	100°C. = +0·000	
		+99·1 +151·7	49·820	150°C. = +0·008	Kew 578 = 0°·0 F.
		+148·9 +201·0	49·807	150°C. = +0·029	584 = 0·1
		+199·2 +250·8	49·747	250°C. = +0·110	585 = 0·1

The length of the column used for the Kew calibration, and by which the thermometers were graduated, was 5°·026 C. for Kew 578, 10°·405 for 584, and 10°·673 for Kew 585. We may, therefore, conclude that between 0° and 100° C. the errors of the three Kew standards, depending on the calibration, are practically insensible; for the errors shown above are too small to be certainly detected, owing to the width and irregularity of the lines which make up the graduation of the thermometer scales.

Accidental errors of graduation could not be guarded against except by the direct examination of every degree, and that accordingly has been done.

The tedious examination of each degree was accomplished with the aid of Professor J. E. Kershner, now of the Franklin and Marshall College, but who was until recently connected with the observatory. We used the apparatus I, and each degree

was measured twice. The resulting means were expressed in terms of hundredths of one division of the eye-piece micrometer, and gave a subdivision of about $\frac{1}{4350}$, $\frac{1}{2330}$ and $\frac{1}{2100}$ of 1° in the cases of Kew 578, 584 and 585 respectively. There were about 2300 separate micrometer readings made, and the result of the reductions shows that no sensible accidental errors have been introduced into the graduations of these standards. The necessary width of the single graduations, taken in connection with the comparatively rough construction of a thermometer tube, prevents any very accurate measures being made; I had prepared for publication the measures we made upon these standards, in order to show what degree of precision we might fairly expect with etched lines of a coarseness sufficient to be readily visible to the naked eye. So much space was occupied by these results however that it now seems hardly expedient to publish them in this place.

The following determination of the boiling and freezing points have been corrected for exposure of stem, and have been reduced to the level of the sea in the latitude of 45°. The latitude of the observing station is 41° 18′; the height of the barometer cistern (and of the boiling point apparatus) is 53 feet above the mean high water of Long Island Sound. Each determination is the mean of from three to five cathetometer readings, and with the exception of the freezing point determinations succeeding the boiling point determinations in the same day, the freezing points were observed after a long exposure (48 hours or more) to a temperature of freezing.

Thermometer.	Date. 1880.	Correction at freezing point.	Correction at boiling point.	Remarks.
Kew 578	Nov. 25	0°·00	----	
	Dec. 1	0·00	----	
	" 1	----	+0°·01	Apparatus VII.
	" 1	+0·18	----	
	" 3	----	+0·04	" VII.
	" 6	----	+0·03	" VII.
Kew 584	Nov. 25	+0·10 F.	----	
	" 26	----	+0·19 F.	" VI.
	" 26	+0·38	----	
	" 26	----	+0·19	" VI.
	" 29	----	+0·20	" VI.
	" 30	----	+0·22	" VI.
	Dec. 1	----	+0·21	" VII.
	" 1	+0·32	----	
Kew 585	Oct. 16	0·00	----	
	Nov. 2	----	+0·15	" VI.
	" 2	+0·10*	----	
	" 29	----	+0·15	" VI.
	" 30	----	+0·15	" VI.
	Dec. 1	+0·22	+0·11	" VII.
	" 1	+0·22		

[To be continued.]

Art. VII.—James Craig Watson.

James Craig Watson, Professor of Astronomy in the University of Wisconsin, and Director of the Washburne Observatory at Madison, Wis., died on the morning of Nov. 23, 1880, after an illness of one week, at the age of forty-two years and ten months. Professor Watson was one of the most gifted and distinguished of modern astronomers, and his life-work is identified with the name of the University of Michigan.

He was born of American parentage, during a sojourn of his parents in Middlesex (now Elgin) County, Ontario, January 28, 1838. The mathematical genius revealed by the boy at the early age of nine, determined the father to secure him a liberal education; and the family accordingly removed to Ann Arbor, in 1850. Here James displayed equal aptitude for mathematical and linguistic studies, and being prepared for college, almost without the evidences of effort, he entered the University of Michigan in the autumn of 1853. He attained equal scholarly distinction as a student of ancient and modern languages, and of mathematics. It is said that before the close of his Junior year, he had performed the phenomenal feat of reading from beginning to end the Mécanique Céleste of Laplace. During his Senior year, he was the solitary pupil of Dr. Brünnow, and graduated in 1857. His mechanical tact was such that in the absence of a mathematical bent he would have become an eminent mechanician and inventor. While in college, some of his spare hours were spent in grinding lenses and the construction of a telescope. Other portions of his time he was compelled to devote to the earning of means to defray collegiate expenses.

During the two years succeeding his graduation, he was employed as assistant in the Observatory, and in the prosecution of studies for his second degree. In this work he displayed such remarkable aptitude as an observer, and such marvelous rapidity in his computations that, on the retirement of Dr. Brünnow, in June, 1859, young Watson succeeded him in the chair of Astronomy. He was already known as a frequent contributor to the American Journal of Science, Brünnow's Astronomical Notices, Gould's Astronomical Journal, and the Astronomische Nachrichten of Altona. Not less than twelve communications written before he was twenty-one are recorded in the Royal Society's Catalogue of Scientific Papers, which also enumerates twenty-one others between 1859 and 1874. His wonderful keenness as an observer was signalized, while yet an undergraduate, by the discovery of a comet on the 29th day of April, 1856, and four months after graduation, by the

discovery of a planet on the 20th of October, 1857, which, however, proved to have been observed by Luther a few days before, and has been named *Aglaia*. His observations of Donati's comet, in 1858, possess a standard value, and his computation of the orbit is recognized as authoritative. The interest awakened by this comet prompted to the preparation of "A Popular Treatise on Comets," published early in 1860.

In 1860, Dr. Brünnow resumed the directorship of the observatory, and young Watson was assigned to the chair of Physics in the University, which he retained for three years, when, on the final retirement of Dr. Brünnow, Watson was made Professor of Astronomy and Director of the observatory—a position which he held and honored for sixteen years. Scarcely had he been clothed with full control of the instruments when he resumed his remarkable career of discovery. There seemed almost a magic in his powers. Unrecognized celestial objects seemed to crowd spontaneously upon his notice. On September 14, 1863, he made his first independent planetary discovery. This was *Eurynome*. On January 9, 1864, he discovered the comet since known as 1863, VI, which Respighi, as it proved, had already noted. On the 9th of October, 1865, he discovered a planet which also proved to have been announced by Peters, and has since been named *Io*. He discovered *Minerva*, August 24, and *Aurora*, September 6, 1867. During 1868, he added no less than six minor plants to the solar system, furnishing the only instance in which the list of planetary discoverers presents the same name four times in immediate succession.

Meantime he was engaged upon a work which might well have engrossed all his powers, and must have quite exceeded the abilities of any but a gifted mathematical genius. It was no less than a complete digest of the results and methods of all the great writers on theoretical astronomy, and an independent development of the great principles of the science. "Having carefully read the works of the great masters," he says in his preface, "my plan was to prepare a complete work on the subject, commencing with the fundamental principles of dynamics, and systematically treating, from one point of view, all the problems presented." This broad plan, conceived by a young man of twenty-eight, and completed when twenty-nine, was executed with ability so commanding, that the work, on its appearance, in 1869, was immediately accepted as an authoritative exposition of the higher principles and processes of dynamical astronomy, and was made a text-book at Leipzig, at Paris and at Greenwich. The same year he was sent by the General Government on an expedition to observe the solar eclipse at Mt. Pleasant, Iowa; and in 1870, to Carlentini, Sicily, for a similar purpose. In 1874 he was appointed to the

charge of an expedition to Peking, China, to observe the transit of Venus. His observations were favored by the weather and conducted with consummate skill. The results, though reduced and discussed, are not yet published. Even at the antipodes, fresh discoveries awaited him. He had already raised his list of planetary discoveries to seventeen, and now added *Juewa*, the eighteenth. In 1876, he was one of the Judges of Awards at the Centennial Exposition, and wrote the celebrated "Report on Horological Instruments." In 1878 also appeared his Tables for the Calculation of Simple and Compound Interest—a work which, in spite of the subject, is marked by great originality, and demanded a vast amount of wearisome labor. The same year he was sent by the General Government in charge of an expedition to Wyoming, to observe the total solar eclipse. Professor Watson, having long entertained a belief in the existence of an intra-mercurial planet, as well as of an extra-neptunian one, gave special attention, at this time, to a search for the former, and was the first astronomer to note certainly (July 29, 1878) the existence and position of the planet Vulcan. He also satisfied himself of the existence of a second intra-mercurial planet. This brought the number of his original planetary discoveries to twenty-six (including one lost July 29, 1873, and two anticipated). He was now animated by an intense desire to control instruments of suitable power and adjustment to confirm his last observations, and enable him to detect the outlying planet beyond Neptune. Coincidently came the invitation to assume the charge of the Washburne Observatory at Madison, Wisconsin, which was to be improved and newly equipped with instruments far more efficient than those at Ann Arbor. The temptation was great, but he naturally clung to his Alma Mater, whose authorities made such efforts as they thought authorized to content their astronomer. But the requisite means could only be obtained by a grant from the legislature—a measure defeated by an inadequate appreciation of the honor shed upon the State by such a name as Watson's. Reluctantly, but sustained by a high and noble aspiration, he removed, in the summer of 1879, to Madison, and immediately devoted himself with intense energy to remodeling the observatory structure, and introducing some original provisions thought to be suited to the special researches on which he was bent. A cellar twenty feet deep was sunk at the bottom of the first slope of observatory-hill. Into this, light was to be thrown through a long tube, from powerful reflectors on the top of the hill. This, with other accessory work, was actually in progress, when a severe cold brought on peritonitis, which over-confidence in his physical powers permitted to reach a fatal stage before medical aid was

summoned. His remains, accompanied by an escort from the University of Wisconsin, were removed to Ann Arbor, where they lay in state, in the university, during the 25th of November, and on the following day, with due honors and imposing ceremonies conducted by his late colleagues, were reverently laid beneath the shade of Oakwood Cemetery.

Professor Watson possessed extraordinary intellectual endowments. His quickness of perception nothing escaped. His mathematical intuitions scorned the ordinary processes of calculation, and gave him a masterly command of mathematical logic and formulæ, which made so many portions of his work on Theoretical Astronomy strictly original, and all parts virtually his own. Yet he never mentions any claim to originality, but pursues his majestic intellectual march with the dignity almost of an inspiration. His memory served him equally well. It was both circumstantial and philosophical. Every new observation was immediately illuminated by all which he had previously observed or known, and he saw instantly the proper conclusions. His mechanical gifts gave him perfect command of instruments and their construction, and the Washburne Observatory would have been equipped with several of his inventions. His versatility extended to matters of business. He was for years the Actuary of the Michigan Mutual Life Insurance Company, and performed service pronounced invaluable. He managed his private means with such success that he died possessed of a considerable fortune which his will secures to the National Academy of Science. Physically, he was vigorous and healthy, and reached in the last years of his life, a weight of two hundred and forty pounds. His religious nature held fast to the fundamental religious beliefs. He used to say it is impossible for a mathematician to be an atheist; and his works offer frequent recognition of the being of the supreme Creator and Governor of the Universe.

The world was not slow to recognize his worth. He was elected a member of the National Academy of Science, in 1867, and of the Royal Academy of Sciences in Italy, in 1870. He received the degree of Doctor of Philosophy from the University of Leipzig, in 1870; and the French Academy of Sciences conferred upon him the Lalande gold medal for the discovery of six new planets in one year. Yale College honored him with the degree of Doctor of Philosophy, in 1871. In 1875, the Khedive made him Knight Commander of the Imperial Order of Medjidich of Turkey and Egypt. He was elected member of the American Philosophical Society in 1877, and received, the same year, the degree of Doctor of Laws from Columbia College.

A. WINCHELL.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the existence of Ozone in the Atmosphere.*—In an elaborate paper upon the reactions hitherto relied on to prove the presence of ozone in the atmosphere, Schöne has discussed the value of the chemical evidence, and concludes that we have at present no test by which the existence of ozone, in the small quantity likely to be present in the air, can be established. Since the author has previously shown that hydrogen peroxide is a normal constituent of atmospheric air, the question now raised is whether ozone is also present. The tests used therefore must discriminate between these two substances. Schönbein proposed three of these tests; the production of free iodine and potassium hydrate from potassium iodide; the oxidation of thallous to thallic oxide; and the oxidation of manganous to manganic oxide. The author has proved that the first two reactions take place readily with hydrogen peroxide; and that the latter requires a trace of ammonium carbonate; the paper then turning brown not only by the peroxide but even by oxygen alone. Houzeau's test, red litmus paper, dipped in potassium iodide solution, also reacts with H_2O_2 as with ozone. The proofs offered by Andrews, that air which acted on potassium iodide, lost this property on heating to 260° or by contact with manganese dioxide, are as well, if not better explained by the existence of H_2O_2 in the air. The only reagent known by which ozone could be absolutely detected is metallic silver. But no observer has yet noticed the blackening of metallic silver in atmospheric air free from sulphur compounds. The author exposed pure silver plates near Moscow for five, six, and seven weeks without change. As to the odor, Schöne says that in 1876 he had the opportunity of trying this, a lightning stroke having taken place in his vicinity. Though entirely familiar with the odor of ozone, there was not the "remotest similarity" between this and the odor produced by the lightning; which recalled more that produced by burning gunpowder. Moreover, it is in proof that, like the electric spark, lightning causes the nitrogen and oxygen to unite, but does not produce ozone, which is formed only by the silent discharge. Again, direct tests with thallium-paper showed no direct relation between the odor and the oxidizing power of a given portion of air. The author by no means denies the existence of ozone in the atmosphere, even coëxistent with hydrogen peroxide, the two reacting on each other very slowly. But he maintains that there is no experimental evidence of its presence.—*Ber. Berl. Chem. Ges.*, xiii, 1503, Sept., 1880. G. F. B.

2. *On the Meteorological use of Thallium-papers.*—Schoene has given in a subsequent paper, the results of an extended series of experiments on the use of thallium-paper for estimating approximately the oxidizing material in the atmosphere, whether

it be hydrogen peroxide alone, or mixed with ozone, or perhaps also with other constituents hitherto unknown. The objection to Schönbein's ozonometer (potassium iodide on starch paper) and to Houzeau's ozonometer (potassium iodide on red litmus paper) lies in the fact that their materials are hygroscopic and their indications vary widely with the moisture of the air. Since dry ozone does not act on these papers, they must be moistened; and then the amount of moisture varies the result quite as much as the amount of ozone. Indeed, attention has been called to the larger amount of ozone near salt-works and waterfalls, and the erroneous opinion advanced that ozone is formed when water is finely divided. And Böttger has stated that ozone is formed when ether is atomized; the fact being that the reaction he observed was due to the H_2O_2 always present in ether. Direct experiments with the Schönbein ozonometer and the psychrometer gave parallel curves; whence the author regards the former as only a crude hygrometer. These objections do not lie against the thallium-paper, the oxidation to brown oxide by either ozone or hydrogen peroxide, not requiring the presence of moisture, and the color therefore being independent of the hygrometric state of the air. Moreover, when well cared for the papers undergo no farther change of color and may be preserved indefinitely. The author prepares the thallium-paper a few days before use, by dipping strips of swedish filtering paper in a solution of thallous hydrate, and drying. The solution is prepared by pouring a solution of thallous sulphate into a boiling solution of barium hydrate, equivalent quantities being taken, the resulting solution of thallous hydrate being concentrated in vacuo until 100 c.c. contains 10 grams Tl(OH). For use the strips are hung in the free air in a close vessel, preferably over caustic lime, for twelve hours. Other papers are used, made with a two per cent solution. These are exposed for thirty-six hours. The coloration is determined by comparison with a scale having eleven degrees of intensity upon it. Compared with Schönbein's ozonometer, the results are in general directly opposite. The thallium papers show that the greatest effect is in the daytime, the iodide papers that it is at night. Yearly curves show that the former generally indicate a rise when the latter give a fall. The iodide curve follows closely that of relative humidity, clouds and rain; the thallium curve stands in no relation to it. A table of results for the year 1879 is given in monthly means, of the two thallium papers, the ozonometer, the relative humidity, cloudiness, rain, and velocity of wind.—*Ber. Berl. Chem. Ges.*, xiii, 1508, Sept., 1880. G. F. B.

3. *On the nature of the Petroleum from the Caucasus.*—Beilstein and Kurbatow have examined the more volatile portions of the petroleum obtained at Baku in the Caucasus, in order to compare this material with American petroleum. It had been observed that the Caucasus fractions had a greater specific gravity than American fractions of the same boiling point; and this fact led to a distrust of the illuminating oils prepared from the

former. But Wilm and Biel showed that these Russian oils had an illuminating power ten per cent higher than the American oils and Biel observed that these oils of higher gravity rose more easily through the wicks. This removed the public prejudice and importation of American petroleum has almost ceased. The samples now examined by the authors were prepared by careful distillation from the natural oil. After nine fractionings, using Glinsky's dephlegmators, no fractions were obtained of constant boiling points, although for the same boiling point, the products showed considerably higher specific gravities than American oils. Thus below 80° the Russian oil had a gravity of 0·717, while American petroleum gives hexane of gravity 0·669. From 80° to 85°, the gravity was 0·733; 85° to 90°, 0·741; 90° to 95°, 0·745; 95° to 100°, 0·748; 100° to 105°, 0·752. American petroleum yields heptane between 95° and 100°, of gravity 0·699. Thinking that this difference might be due to a mixture of the hydrocarbons C_nH_{2n-6} with the ordinary C_nH_{2n+2} series, the fraction 80° to 85° was agitated with fuming sulphuric acid; but no trace was detected. Analysis gave C 85·23, H 15·11; which corresponds more nearly to C_nH_{2n}; showing that the Caucasian petroleums are poorer in hydrogen than the American. But these hydrocarbons are not homologues of ethylene, since bromine does not act on them in the cold. When warmed, decolorization ensues but with evolution of HBr, proving substitution. Further study proved that the hydrocarbons of Caucasian petroleum were identical with the addition-products of hydrogen to the aromatic hydrocarbons C_nH_{2n-6}. As examined by Wreden, these are:—hexahydrobenzene C_6H_{12}, gravity 0·76 at 0°, boiling point 69°; hexahydrotoluene C_7H_{14}, gravity 0·772 at 0°, boiling point 97°; and hexahydroisoxylene C_8H_{16}, gravity 0·777 at 0°, boiling point 118°. The petroleum-products confirmed Wreden's data entirely, being exceedingly indifferent to chemical reagents. From the fraction 115° to 120°, containing hexahydroisoxylene, trinitroisoxylene was prepared identical with that from metaxylene. Heated on the water bath with fuming sulphuric acid, the hydrocarbon is charred and destroyed, yielding no sulpho-acid. When the fraction 90° to 95° is dissolved in a mixture of one part nitric and two parts sulphuric acid, CO_2 is steadily evolved and nothing separates on dilution with water. One part of the fraction 95° to 100° boiled with four parts nitric acid of 1·38 until red vapors cease, gave an acid liquid containing acetic acid, considerable succinic acid and a large quantity of oily non-volatile acids. The supernatant oily layer gave on fractioning, a distillate between 101° to 103°, essentially hexahydrotoluene; and a second, 210° to 215°, having the formula $C_6H_{11}NO_2$ either a nitro-product or a nitrous ether.—*Ber. Berl. Chem. Ges.*, xiii, 1818, October, 1880. G. F. B.

4. *On a new Hydrocarbon from Sequoia gigantea.*—Lunge and Steinkauler have published a preliminary note on certain products obtained from *Sequoia gigantea* Torr. Stems about three meters long, furnished by Fröbel & Co., gardeners in

Zürich, were used for the preparation of these products. The needles, in which the peculiar odor seemed to be most abundant, were stripped from the twigs and distilled with water in a large copper retort in a current of steam from a boiler. The distillate was agitated with ether and the ether distilled off. The early portions of the distillate gave only a solid residue, the next gave a mixture of solid and liquid, and the last portions only an oil. The solid substance was with some difficulty obtained crystallized. It is very soluble in alcohol, ether, benzene and chloroform. In ligroin (petroleum naphtha) it is less so. In glacial acetic acid, it is soluble only on heating. By covering its solution in this acid with a layer of water, the gradual solution of the acid caused a deposition of this body in small crystal plates, fusing at 105°. They are white, have a bluish fluorescence, and possess the penetrating aromatic odor of Sequoia in a high degree. When thus concentrated, it recalls the odor of peppermint. Its boiling point was between 290° and 300°, and it gave on analysis C 93·55, H 6·09, corresponding to the formula $C_{13}H_{10}$. Its vapor density by v. Meyer's method, was 81·7; the above formula requires 83. This empirical formula is that of fluorene; but its fusing point and general properties distinguish it from this body. The authors give it the name *sequoiene* and are engaged in its study. The liquid distillates gave: (1) a colorless oil boiling at 155°; (2) a slightly yellow oil, fusing point 190°–200°; (3) a yellow oil fusing at 240°; and (4) a solid body fusing at 290°–300° evidently sequoiene.—*Ber. Berl. Chem. Ges.*, xiii, 1656, Sept., 1880.

G. F. B.

5. *On Bäyer's Synthesis of Indigotin.*—Rosenstiehl has given a summary of the processes discovered and patented by Bäyer for the synthesis of indigotin. The point of departure in both of these is cinnamic or phenyl-acrylic acid, $C_6H_5(C_3H_3O_2)$. Nitric acid produces from this nitrocinnamic acid, the nitryl occupying the ortho position in that form of the acid which yields indigotin. The orthonitrocinnamic acid is transformed by known processes either into orthonitrophenylpropiolic or into orthonitrophenyloxyacrylic acid, according to the process to be followed subsequently. To transform it into orthonitrophenylpropiolic acid, the orthonitrocinnamic acid is brominated, giving $C_6H_4(NO_2)(C_3H_2Br_2O_2)$. By the action of alkali in boiling alcoholic solution $(HBr)_2$ is removed, leaving $C_6H_4(NO_2)(C_3HO_2)$ orthonitrophenylpropiolic acid. To produce orthonitrophenyloxyacrylic acid, the orthonitrocinnamic acid is treated with hypochlorous acid, which by addition gives orthonitrophenylchlorolactic acid, $C_6H_4(NO_2)(C_3H_4ClO_3)$. This, treated with boiling alkali in alcohol, gives orthonitrophenylacrylic acid $C_6H_4(NO_2)(C_3H_3O_3)$. By the action of heat alone orthonitrophenylacrylic acid is converted into indigotin, thus:

$$C_9H_7NO_5=C_8H_5NO+CO_2+H_2O+O.$$

The reaction takes place at 110° C. The mass swells, its color gradually darkens, and, treated with alcohol, it leaves a residue

of indigotin. The yield is small, however, owing to the formation of secondary products. With orthonitrophenylpropiolic acid however, the united action of an alkali and of a deoxidizing body is required, the reaction proceeding regularly:

$$C_9H_5NO_4+H_2=C_6H_5NO+CO_2+H_2O.$$

Bäyer recommends the use of a mixture of glucose and an alkali carbonate. The transformation takes place at 110° C. and the indigotin separates in the crystalline form. Hence Bäyer prefers the second process. But it has a still greater advantage, since the above reaction may be effected directly upon the cloth. The fiber is printed with a mixture of the orthonitrophenylpropiolic acid, glucose and the alkali carbonate and is then exposed to superheated steam. The indigo blue is developed directly upon the fiber permanently. This fact will give the artificial indigo a great advantage over the natural product. The possibility of producing other indigotines by effecting substitutions in the phenyl group which it contains, promises important results.—*Ann. Chim. Phys.*, V, xxi, 286, Oct., 1880. G. F. B.

6. *On Isopropylene-neurine.*—Morley has prepared, in the laboratory of Ad. Wurtz, a neurine containing oxyisopropyl in place of the oxethyl in normal neurine. By the action of 20 grams isopropylene-chlorhydrin upon 37 grams of a 33 per cent solution of trimethylamine for several hours on the water bath, a neutral liquid resulted which gave a platinum salt of the composition $C_{12}H_{32}N_2O_2PtCl_6$. The propylene-neurine chloride crystallizes in colorless transparent crystals, very deliquescent, and which turn brown in the air.—*Ber. Berl. Chem. Ges.*, xiii, 1805, Oct., 1880. G. F. B.

7. *Notice of the investigation of* Dr. J. W. Bruhl *on the Relations between the Molecular Structure of Organic Compounds and their Refractive Power.* (Liebig's Annalen, cxcix, 139 and cciii, 1.)—The study of the relations between the physical properties of chemical compounds and their molecular structure has opened a new field to the science of chemistry. A remarkable investigation of Thomsen into some of the thermal relations of molecular structure, we shall notice in another number of this Journal. We now call attention to an attempt to study the molecular structure of bodies by optical means. Unfortunately the results of the two investigations do not wholly harmonize with one another; yet in both cases the new method of investigation is the chief point of interest, and we have every reason to hope that by carefully comparing the different methods of solving the same problem the truth may ultimately be reached.

If we denote by μ the index of refraction of a body the excess of this index over unity or $(\mu-1)$ represents what has been called the refracting power of a body, and since the refracting power increases in general with the density (δ) we obtain by dividing the refracting power by the density a quantity $\left(\frac{\mu-1}{\delta}\right)$ which is, essentially, independent of mere changes of physical condition, and depends on

the chemical relations of the substances. This quantity has been called the specific refracting power, and if we now multiply by the molecular weight of the substance we have in $M\left(\frac{\mu-1}{\delta}\right)$ the specific refracting power of the molecule, or as it has also been called the refractive equivalent of the substance. In 1864 (Pogg. Ann., cxxiii, 595) Landolt showed that a difference of one atom of carbon, hydrogen or oxygen, between two organic compounds corresponded to a constant difference for each elementary substance in the specific refracting power of the molecule, and having thus fixed what he called the refractive power of each atom he made the generalization that the refractive power of the molecule was simply the sum of the refractive powers of its constituent atoms. For example:

TABLE I.

		$M\left(\frac{\mu-1}{a}\right)$	Diff.
	Differing in composition by C_1.		
Methyl alcohol	CH_4O	13·17	5·41
Aldehyde	C_2H_4O	18·58	
	Differing in composition by H_2.		
Aldehyde	C_2H_4O	18·58	2·12
Ethyl alcohol	C_2H_6O	20·70	
	Differing in composition by O_1.		
Aldehyde	C_2H_4O	18·58	2·53
Acetic acid	$C_2H_4O_2$	21·11	

The differences show the refractive power of one atom of carbon, one atom of oxygen and two atoms of hydrogen and the following values are in each case, the mean of a very large number of comparisons similar to those just given.

TABLE II.

	r_a	r_A
C	5·0	4·86
H	1·3	1·29
O	3·0	2·90

Of course these values are based on the determination of the index of refraction, and the density of each of the substances thus compared. The observations of density were readily reduced to standard conditions which might be arbitrarily selected, but in consequence of the very unequal and irregular dispersive power of the different substances compared it was by no means a matter of indifference which of the lines of the spectrum was selected for the index of refraction. In his own experiments Bruhl determined the index of refraction for the sodium line D and also for the three bright hydrogen lines, and by means of these data he calculated according to Cauchy's formula the index of refraction corresponding to a wave length of indefinite length, and from these calculated indices the values r_A are derived. Data thus reduced are regarded by Bruhl as furnishing the more correct

basis for all comparisons of molecular refractive powers, but the results are nearly as satisfactory when deduced from the indices observed with the red light of the hydrogen spectrum. The values r_a were thus obtained.

If now we compare the molecular refractive powers calculated from the atomic composition (R_a) with those deduced from direct observations on the densities and indices of refraction of the compounds—$M\left(\frac{\mu_a - 1}{\delta}\right)$—we shall find that in the case of a large number of organic products the generalization of Landolt is very closely confirmed, thus:

TABLE III.

		$M\left(\frac{\mu_a-1}{\delta}\right)$	R_a	Diff.
Propylalcohol	C_3H_8O	28·6	28·4	+0·2
Propylaldehyde	C_3H_6O	26·0	25·8	+0.2
Propylethyl ether	$C_5H_{12}O$	43·8	43·6	+0.2
Propylacetate	$C_5H_{10}O_2$	44·0	44·0	0·0
Propylchloride	C_3H_7Cl	34·1	33·9	+0·2
Isobutyric acid	$C_4H_8O_2$	36·3	36·4	−0·1
Hexan	C_6H_{14}	48·6	48·2	+0·4
Tri-ethylamine	$C_6H_{15}N$	55·3	55·3	0·0

If then the molecular refractive power is simply the sum of the atomic refractive powers it must be the same for all isomeric bodies and therefore independent of their molecular structure, and so Landolt thought. In 1870, however, it was shown by Gladstone (London Chem. Soc. Jour., viii, 147) that there were many organic compounds, especially those belonging to the aromatic family, whose molecular refractive powers differed from the values calculated by Landolt's formula so widely, that the discrepancies could not possibly be referred to errors of observation. The residuals thus observed although not satisfactorily explained by Gladstone form the starting point in the investigation of Bruhl, who traces the effect to the mode of linking of the multivalent atoms in the molecule. He concludes in general that, while the univalent atoms of hydrogen, chlorine, bromine and iodine, have an invariable refracting power, the refracting power of multivalent atoms changes when they unite with each other by more than one bond. The values given in table II only hold rigorously, when no two atoms are united by more than a single bond, and the close agreement shown in table III depends on the circumstance that the molecules of all the substances therein named, however variable their structure in other respects, have this one feature in common. Hence all isomeric bodies have the same molecular refractive power, provided the differences of molecular structure do not extend to the relation we have named; and the discrepancies observed by Gladstone arose from the circumstance that in the molecules of the bodies he chiefly studied two or more of the carbon atoms were linked by double or treble bonds.

By comparing the molecular refractive powers of bodies containing doubly or trebly linked multivalent atoms, after the

method illustrated by table I, Bruhl has determined the effect of the double and treble links in the case of carbon, and of the double links in the case of oxygen, on the atomic refracting power, and has thus obtained the data for the following table. In this table C′ C″ C‴ indicate carbon atoms singly, doubly and trebly linked with each other, and O″ an atom of oxygen doubly linked to an atom of carbon, and in order that the values given may be used in calculating the molecular refractive power of organic compounds it must be further noticed that the value for the group $-\overset{\overset{O}{\|}}{C}-$ is $5+3{\cdot}4=8{\cdot}4$ and that for the group $-\overset{|}{C}=\overset{|}{C}-$ is $2\times 6{\cdot}15=12{\cdot}3$.

TABLE IV.

	r_a	r_A
C′	5·00	4·86
C″	6·15	5·86
C‴	5·95	5·76
O′	2·80	2·71
O″	3·40	3·29
H	1·30	1·29
Cl	9·80	9·53
Br	15·30	14·75
T	24·90	23·55
N′	5·80	5·35

With these data it is now easy to calculate the molecular refractive powers of the greater number of organic compounds, not only the parafines and their derivatives in which the carbon atoms are usually singly linked, but also the olefines, the acetylenes and the aromatic bodies, in which the complexity of the structure is increased by double or treble links. In the original papers such results are compared with the molecular refractive powers calculated by Landolt's formula from the index of refraction and density, measured with every refinement, and with materials of undoubted purity. In almost all cases the agreement is exceedingly close especially when the observations are reduced by Cauchy's formula so as to eliminate the effect of the irregular dispersive powers of the substances compared. We have not however room to reprint the numerous tables or to describe the details of the investigation which involve many incidental points of great interest. It must be sufficient to say that the papers show that the work has been done with all the care and refinements of which the methods used are capable, and limit ourselves to a description of one only of the important conclusions to which the investigations points.

It is obvious that, when a question in regard to molecular structure turns on the existence or absence of multiple bonds, the calculated molecular refractive power will not be the same in the two cases and then the index of refraction and the density of the substance may give us the means of testing our hypothesis. As is well known there has been a question in regard to the molecu-

lar structure of benzol, C_6H_6. According to the well known theory of Kekulé the six carbon atoms form a ring and are united by three single and three double bonds; but according to the theory of Ladenburg, the bonds in this structure are all single, each carbon atom being united with two of the other carbon atoms of the ring. The principles developed by Bruhl give him a new test of the theories in question since the molecular refractive power should be six units higher with the structure of Kekulé than with that of Ladenburg, and as the value deduced from the observed index of refraction and density of benzol gives a result which very closely agrees with the larger of the two values, Bruhl concludes that the generally received theory of Kekulé is "the only one which harmonizes with the physical as well as the chemical relations of the aromatic compounds."

J. P. COOKE.

8. *Chemical Energy and Electromotive force of different galvanic elements.*—THOMSEN reviews his earlier work upon this subject and makes a new and careful determination of the chemical energy and the electromotive force of a Daniells cell. According to his later measurements, the total devlopment of heat by galvanic means in all parts of the Daniells element amounts to 50292 units of heat during the time in which one molecule of copper sulphate ($CuSO_4$) is reduced. A calculation of the value of the energy of the chemical processes in the cell gives 50130 units. The difference between 50292 and 50130 is so small that Thomsen concludes that the total chemical energy of a Daniells cell is converted into electricity and the development of heat in the circuit is the equivalent of the chemical energy developed by the cell. Other forms of cells are then investigated from this point of view and the same conclusion is reached in the case of zinc-cadmium elements and chloride of silver elements, or in general wherever the metallic surface of the negative electrode is not changed by the electrolytic process.—*Ann. der Physik und Chemie*, No. 10, 1880, p. 246.

J. T.

9. *Spectra of the compound of Carbon with Hydrogen and Nitrogen.*—Professors LIVEING and DEWAR used in their experiments a DeMeritens dynamo-electric machine which produced the voltaic arc in the different gases they experimented upon. It was found that the indigo, violet and ultra violet bands characteristic of the flame of cyanogen are conspicous in the arc taken in an atmosphere of nitrogen, air, nitric oxide or ammonia, and disappear very nearly in a non-nitrogenous atmosphere of hydrogen, carbonic oxide, carbonic acid, or chlorine. These bands are seen in the flame of cyanogen and hydrocyanic acid, but are not seen in those of hydrocarbons, carbonic oxide, or carbon disulphide. The authors therefore conclude that they belong to cyanogen, and support this conclusion by reference to various facts. Their experiments on the spectrum of carbon are at variance with those of Lockyer on the same subject. They state that the evidence that carbon uncombined can take the state of vapor at the tempera-

ture of the electric arc is very imperfect; and they believe that any reasoning based upon the absence of nitrogen is imperfect, for it cannot be shown conclusivly that nitrogen has really been absent in the experiments hitherto conducted. They contend against the hypothesis that if cyanogen bands are present in the solar spectrum they are due to vapors of carbon uncombined in the upper cooler region of the chromosphere. It appears to them that nitrogen may be recognized in the solar atmosphere through cyanogen when free nitrogen might not be detected.—*Proc. R. S.*, xxx, pp. 152, 494. *Nature*, Oct. 28, 1880. J. T.

10. *On the behavior of gases under the influence of electrical discharges.*—Professor E. WIEDEMANN in a paper not yet concluded, describes his method of experimenting and gives some preliminary results. He arrives at a confirmation of fact previously stated by him: that a gas may be rendered luminous by electric discharges without any corresponding elevation of temperature.—*Ann. der Physik und Chemie*, No. 6, 1880. J. T.

11. *A theoretical and practical treatise on the manufacture of Sulphuric acid and Alkali;* by GEORG LUNGE. Vol. II. London: 1880.—Dr. Lunge's second volume quite sustains the character which the first so justly won, of being the most correct and exhaustive treatise yet published on the subject of which it treats. The first was confined to the manufacture of sulphuric acid—the starting point in almost every chemical industry. The second is occupied by that of carbonate, bicarbonate of soda and caustic soda. Every operation, as well as the plant for carrying it out, is described with minuteness and illustrated by drawings to scale.

This volume will excite less interest than the first in as much as the manufacture of sulphuric acid is very general, while that of alkali is in this country conducted by but few firms and by these on a very limited scale; yet a study of the technical and commercial bearing of this great industry is therefore the more necessary, in order to determine whether its exclusion from the list of American enterprises is due to remediable or irremediable causes. In Europe only at certain favored centers, where sulphur, coal, salt and limestone are cheap, can alkali be economically manufactured. If there be any such in this country not far removed from the centers of consumption, the alkali trade may take the place it occupies in Europe, and notably in Britain, as second only to the iron trade. Unless, however, this combination of materials occurs in one or more favorably situated localities, the Mersey, the Tyne and the Clyde must continue to supply with alkali our glass and soap makers. The problem yields in importance to none.

The mention of the above materials, used in the Leblanc process, is due to the fact that as yet none of the many substitutes proposed for it, cumbersome and wasteful as it is, have been successfully introduced. Our author reserves for a third volume a description and discussion of the ammonia process and of the manufacture of alkali from cryolite, as practiced exclusively in this

country by the Pennsylvania Salt Co. But he gives full details of the plant, and manipulation for the method proposed by Hargreave for the manufacture of sulphate of soda direct from salt by the action of sulphurous acid,—thus reducing to one the double operation of first making sulphuric acid and then decomposing by it the salt. Although not generally adopted and far from perfected, it deserves to rank as the most important recent modification of the Leblanc process.

The operation may be expressed by the following equation: $SO_2+O+H_2O+2NaCl=Na_2SO_4+2HCl$. It is effected by drawing, by means of a Root exhauster, sulphurous acid gas, with 6 to 8 vols. of sulphurous acid, from ordinary pyrites burners, mixed with superheated steam through a series of connected cylinders, filled with salt. Complete decomposition is not effected in less than two to three weeks. Hence, owing to loss by radiation, the heat generated by the chemical action has not in practice been found —contrary to expectation—sufficient to maintain the contents of the cylinders at the requisite temperature of 400° to 500°. Therefore the fuel consumed in heating the cylinders, raising steam and preparing the salt, almost equals in some works that consumed in making sulphate in the old way.

In the appliances for converting the sulphate into carbonate no radical improvements have been made of late years, if we except the revolving black ash furnace. But the attention of manufacturers has been of necessity directed to condensing all deleterious escaping gases and rendering harmless all fluids, before discharging them into any water courses; for the several Alkali and River Pollution Acts of the British and other European parliaments define the amount of impurity which may be thrown into the air, or discharged as drainage. It has been found very easy to condense very perfectly the gases, but not so easy to deprive the liquors flowing from the vast accumulation of soda waste, that encumbers old works, of their offensive character. An economical reward has, however, followed the compulsory performance of this public duty; for the result at all works has been the recovery from the tank waste of 40–60 per cent of the sulphur originally used. The process most in favor is that of Mond, which consists like most others in oxidizing the insoluble CaS of the waste into soluble CaS_2O_3, and then separating the S from the solution by HCl. Mactear, at the St. Rollox works, treats the yellow liquors as they flow from the waste heaps with SO_2. But the most recent and thorough method, as described by our author, and one which, if practicable, will raise the Leblanc to the rank of a regenerative process, has been proposed by Schaffner and Helbig. By the aid of $MgCl_2$ they convert CaS into $CaCl_2$ and generate H_2S.

I. $CaS+MgCl_2+H_2O=CaCl_2+MgO+H_2S$.

II. The H_2S is drawn off and the S separated by SO_2,—the difficulty heretofore always experienced of collecting the extremely fleecy sulphur being overcome by bringing the gases into contact with such salts as calcium or magnesium chloride, when

dense granular sulphur separates and none passes off as polythionic acids.

III. The $CaCl_2$ under the action of CO_2 restores $CaCO_3$—the reagent for carbonizing the $NaSO_4$ of another lot; and the Cl passes back to the manganese for use again.

$$MgO+CaCl_2+CO_2=MgCl_2+CaCO_3.$$

If this beautiful series of reactions can be carried out in practice the names of Schaffner and Helbig will deserve a place in the list of industrial chemists next to that of Leblanc himself. J. D., JR.

II. Geology and Natural History.

1. *Notes on alleged changes in the relative elevations of Land and Sea;* by Henry Mitchell, Assistant. Appendix No. 8 in the Report of the Coast and Geodetic Survey for 1877, Carlile P. Patterson, Superintendent.—The author alludes to the impression that the northeastern coast of the American Continent is so rapidly rising that the change of depth over rocky bars upon the coast of Maine has been noticeable within a generation of practical boatmen; and mentions Professor Shaler's estimate of the emergence in progress as probably over a foot in a century, and perhaps as much as three feet. The author of this memoir, who was assistant under Professor Bache in the work of establishing benches at all the tidal stations along the coast of Maine, gives as the result of his study of the subject, the following conclusions:

(1) That the attention of early explorers was attracted by the salt marshes, which broke the monotony of our otherwise then wooded country, and that these were then, as now, at ordinary high-water level.

(2) That rocks upon our coast, long notorious as dangerous to navigation, have not risen since they were first discovered.

In his statements ancient maps and documents are cited, and the conditions of the various rocks are considered in detail. The memoir concludes as follows:

"From the foregoing it has been seen that the study thus far extends from Wood's Hole, latitude 41° 31′, longitude 70° 39′, to Percé Rock, latitude 48° 30′, longitude 64° 13′, embracing 7° of latitude (420 nautical miles) and 6° 26′ of longitude (266 nautical miles). It would, of course, be quite unwarrantable to conclude that a parallelogram with these limits has remained unchanged, but a smaller district may be claimed as beyond dispute. If, confining ourselves to Champlain's points, we draw a line from Green Ledge to Annapolis, Nova Scotia, thence to Wells, in Maine, thence to Gloucester, thence to Mary Ann Rocks, thence to Harwich, Massachusetts, thence to point of beginning at Green Ledge, we inclose a district of 20,000 square miles. Within this district lie Trinity Rocks, and near it Harding's and Brazil, which have not changed during the past century; so that it is fair to conclude that no tilt in either direction has taken place in the Gulf of Maine. The arc of the meridian between Green Ledge

and Percé Rock, measuring two hundred and seventy-one nautical miles, passes near the *Grand Pré* and across the meadows of the Cumberland Basin. It is to these two salt-marsh districts that Mr. Akins refers particularly in his letter already quoted, when he speaks of the ancient French and modern English dykes with the conclusion that no change of elevation can be alleged. So that we have really four stationary points in this arc.

I must, in closing, reiterate that to the eastward of this meridian, and especially in Newfoundland, great changes present themselves in the comparison of charts, the depths appearing to be at some points less and at other points greater now than formerly."

2. *Further discoveries of fossils in the Wappinger Valley or Barnegat limestone;* by Professor W. B. Dwight, of Vassar College, Poughkeepsie. (From a letter to J. D. Dana, dated Dec. 11, 1880.)—In extending my explorations in the Wappinger Valley limestone I discovered at Rochdale, east of Poughkeepsie, N. Y., on Oct. 28th, a limestone locality affording great numbers of Orthocerata and of other fossils, many of which are not reported as occurring in New York State. The Orthocerata present quite a variety of sizes and shapes; but all agree in showing the large number of septa so characteristic of formations below the Trenton and Black River. The lengths vary from $1\frac{1}{2}$ inches to 9 inches, the widths from $\frac{3}{8}$ to $1\frac{1}{2}$ inches; the septa vary from thirty to forty to the inch in some specimens, to eleven to an inch in others. These fossils are more or less scattered through a ledge for at least 1,500 feet, and at one point, for about fifty feet, they are so crowded that one can hardly be taken out without disturbing several others.

There are also here abundant specimens of discoidal gasteropods, some of which are an inch and a half in diameter; a large turreted gasteropod, probably Cyclonema, about three inches in length; and two small Atrypa-like brachiopods.

This formation is entirely different from the adjoining Trenton limestone, both in its lithological nature and in its fossils. It is, however, apparently identical in its physical characteristics with the adjacent formation which I have already assigned, on fossiliferous evidence, to the Calciferous, (this Journal, vol. xix, p. 50, Jan., 1880), and concerning which I see no reason to change my opinion. It appears, also, in addition to its own peculiar and striking fossils, to contain the characteristic fucoids and the other fossils of the adjacent Calciferous. It would be premature to offer any decided opinion as to the stratigraphical position of this remarkable rock before the fossils have been carefully studied; but I may say that while it reveals a wealth of cephalopodic life, of a character and abundance hitherto unknown in the United States in any formation to which this is likely to belong—i. e. below the Trenton and Black River strata,—it is at least very closely related to the Calciferous, and in its numerous Orthocerata is like the Calciferous and the Quebec groups of Canada. I am collecting and carefully examining the specimens, (of which I have

already from 150 to 200,) with reference to giving full details and further results in a future paper.

3. *Volcanic Eruptions of Mauna Loa, Hawaii.*—A letter of November 9th to 12th, from the Rev. Titus Coan of Hilo, addressed to Prof. C. S. Lyman of New Haven, states that, on the 6th, vapors were seen toward the summit of Mauna Loa and evidence of a flow of lavas in progress toward Mauna Kea. On the 7th, according to the report of a person from Waimea who had ascended for a view of the region one of the spurs of Mauna Kea, all the elevated plain between Mauna Loa and Mauna Kea was a sea of glowing lava, and from it a current was flowing off eastward toward Hilo. Mr. D. Hitchcock, who visited the region of lavas between the mountains, on the 9th, states that the stream was on the north side of the flow of 1855–56, had a length to the plain of about thirty miles, and was three-fourths of a mile wide at its terminus. Heavy clouds from the escaping vapors concealed the region of fires the most of the time from observers at Hilo. On the 10th, the eastward stream was distinguished by the brilliant light for a length of twenty miles, running southeasterly toward East Kau or Kilauea. On the 11th the fires were still active from the summit downward. The "fountain-head" had not been visited, but Mr. Coan judged that it was to the north of the summit crater near the point of eruption of 1843, which was about 13,000 feet above the sea-level; and he states that adding thirty miles for the length of the southeast branch, it makes a continuous line of flow of sixty miles.

The Commercial Advertiser of Honolulu for November 20th contains notices from which the following facts are taken. The eruption began on the evening of the 5th without any violent demonstrations or earthquake. The river of fire from the summit, as seen at night, was a continuous line of light. The whole front edge, about three-fourths of a mile wide, was intensely brilliant; and as it slowly advanced and rolled over the small trees and shrubs, bright flames would flash up and die out along its whole edge. Every now and then there was a report like that of cannon, made probably by the escape of steam from waters that were caught beneath. According to a describer who went within twenty feet of the eastern stream, then very sluggish, its broad extremity, along the whole front, was a bright-red mass of solidified lava, twelve to thirty feet in height, moving slowly along by breaking and bearing on the crusted covering; "it was one crash of rolling, sliding, tumbling, red-hot rock, no liquid rock being in sight; there were no explosions, but a tremendous roaring, like ten thousand blast furnaces all at work at once." Such a flow makes what are called on Hawaii *aa*, or clinker-fields. The rough blocks lie piled together in the wildest confusion, many as large as ordinary houses. They form only when the movement is slow. Fears were at first felt that the eastern stream would descend to Hilo.

4. *The Genesis of the Ores of Iron*, by J. S. NEWBERRY. (From the School of Mines Quarterly for Nov., 1880).—Iron-ore deposits, including those of the Archæan, are shown by Dr. Newberry to be of sedimentary origin, and their formation through the aid of organic acids is sustained. Speaking of the Archæan iron ores, he says: "That in some cases the ore has been profoundly modified, both in character and position, since its deposition, is undeniable; but to be asked to believe that the ore sheets are intrusive is a greater strain upon my credulity than it can endure."

The magnetite and hematite ores in southern Utah, which Prof. Newberry was the first to describe, are situated 300 miles south of Salt Lake City, in what is really the prolongation of the Wahsatch Mountains. He observes that near Iron Springs, the so-called "Big Blow out" is a projecting mass of magnetite iron ore, measuring probably 1000 feet by 500, rising in castellated crags 100 feet or more above its base. The "Blair Mine" is a ragged black crest of magnetite, 200 to 300 feet high. The ore of the region, which is half hematite, is in belts standing nearly vertical; it is often intersected by thin layers of quartz, or jasper, and occasionally by zones of crystals (2 to 3 inches long) of apatite. The containing rock is granite, of a finer kind than that of the Wahsatch axis; "some of the ore beds are interstratified with the granite, and are certainly, like it, metamorphosed sediments," as is well seen at the Blair-Mine. Prof. Newberry states that no eruptive iron ore exists in the Rocky Mountains, and that in the opinion of Prof. Otto Torell, Director of the Geological Survey of Sweden, the ores of Sweden are metamorphic and not eruptive.

5. *Descartes l'un des Créateurs de la Cosmologie et de la Géologie;* par M. DAUBRÉE. 27 pp. 4to. (Journal des Savants, March, April, 1880).—Prof. Daubrée, in this interesting memoir, cites from Descartes' remarkable work his descriptions and the illustrating figure, which show—especially the latter—that he had conceived the idea of mountain making, or the displacement of strata, through movements, contraction-like, beneath the earth's surface. He also points out that Descartes attributed the formation of mineral veins to emanations from below.

6. *Geological map of a portion of the Southern Interior of British Columbia*, by G. M. DAWSON. Montreal, July, 1880.—This colored map, about 21 inches square, shows the geological formations over a region directly north of the U. S. boundary between the meridians of 118° and 122°, Great Shuswap Lake being in the northeast corner. The Triassic covers large areas, but uncertainty remains as to their outline; the areas of the Cretaceous and Tertiary deposits are much smaller. Tertiary volcanic rocks cover a wide region.

7. *Application of Organic Acids to the examination of Minerals.—Second paper;* by H. CARRINGTON BOLTON, Ph.D.—This paper forms a continuation of those already published by Prof. Bolton upon this subject. It gives the results obtained by sub-

jecting a large number of minerals—upward of 100—to the action of citric acid, in some cases with the addition of a second reagent, as sodium nitrate, potassium iodide, etc. It is concluded that all carbonates and phosphates are decomposed by citric acid, some sulphides, and all the hydrous silicates with one or two exceptions. A series of tables are given at the end of the paper in which some ninety minerals are arranged according to their behavior with citric acid, with and without the addition of other reagents. The memoir gives proof of much patient labor, and the field is one in which little had been done previously.—*Annals N. Y. Acad. Sci.*, ii, No. I.

8. *Proceedings of the Academy of Natural Sciences of Philadelphia.*—For the convenience of those interested in Mineralogy and Geology, the papers of the Proceedings of this Academy in these departments for the years 1877–1879, have been issued as a separate pamphlet, and made Number 1 of a proposed series.

9. *Ctenophoræ*;* by Dr. C. CHUN. — This volume forms the first monograph of the Memoirs to be published under the auspices of the Zoological Station at Naples. As Dr. Dohrn informs us in the introduction, there are no less than twenty monographs now in preparation, all based upon the rich materials to be found in the Bay of Naples. The subjects of these monographs have been so far circumscribed that Dr. Dohrn hopes little by little to succeed in accomplishing the task of "sweeping before his own door," and giving us a complete history of the Fauna and Flora of the Gulf. If the succeeding monographs can be maintained to the high standard set for them by the first of these publications, they will form a series of faunistic biological monographs without a parallel, and present a model which few biologists can hope to excel. Dr. Dohrn has here shown far better than by any verbose report, the value to science of stations like the Zoological Station at Naples. A few such stations distributed along the shores of the Atlantic and Pacific, so selected as to bring faunal districts as dissimilar as possible, within easy reach of the investigator, and biology would be revolutionized. Our embryological and anatomical journals have been so flooded with disconnected papers upon all classes of invertebrates that only careful faunal monographic biological studies connecting the chaos of independent observations into a homogeneous whole, will drag us out of this sea of contradictions, and enable us to survey anew the field of biology, unencumbered by the drift-wood through which every worker has now to make his way. Biologists cannot be too grateful to Dr. Dohrn for his patience in waiting until he could publish a monograph comprehensive enough to cover not only the systematic work, but to include also the anatomy, the embryology, in fact the whole biology of the group understood in its broadest sense.

* Fauna u. Flora des Golfes von Neapel. Herausgegeben von der Zoologischen Station zu Neapel. I Monographie, Ctenophoræ, von Dr. Carl Chun, 4to, pp. xviii, 313, mit 18 Tafeln u. 22 Holzschnitten. Leipzig, 1880. (Wilhelm Engelmann.)

With the intense competition for priority which rapid publication has introduced into all biological work, it is most gratifying to see a student who, instead of rushing into print at the end of every three months, and inflicting on his brother naturalists his undigested notes of a season's work, sits down for four years of quiet investigation and then gives us the result, a masterly monograph, such as Dr. Chun has just published, upon Ctenophoræ. We trust the volume before us may not only bring into vogue again carefully prepared monographs, but that we may also find in them the same modesty and the same good temper which characterizes every page of this magnificent memoir. It is rare to find so gentle a critic and yet one who, combining original investigation of the first order with an exhaustive knowledge of the literature of his subject, is yet able and willing to place himself on the ground occupied by his predecessors, and judging them by the standard of the time at which they wrote—never extolling the progress of later days, at the expense of the pioneers.

It is not too much to say that the Revision of the Ctenophoræ, given by Dr. Chun in this faunistic monograph, makes this memoir by far the most valuable one ever published on the Ctenophoræ. There is hardly a point in the habits, in the anatomy, in the embryology, or in the systematic working up of the group, which has not been greatly advanced by the light thrown upon it by Dr. Chun. And while we may differ radically from him in regard to some of his views respecting the affinities of Ctenophoræ, their relationship to Echinoderms and Polyps, and the typical structure underlying them, we cannot fail to be struck with the original method of presenting these views, and the candor and fairness with which opposite opinions are discussed.

This memoir is remarkable for the great thoroughness with which all histological points are discussed, the neatness of the minute anatomy necessary to follow the complicated structures of Ctenophoræ, and the perseverance shown in tracing the post-embryonic stages of so many genera. This perhaps is the most valuable feature of this notable memoir. No family has been left in the dark, and the flood of light which these studies have thrown on the systematic relationship of the other Ctenophoræ is indeed wonderful. By far the most interesting page of this chapter is the complete development given us of Cestus. This genus theoretically promised to do more than any other towards unravelling the affinities of the Ctenophoræ, and Dr. Chun's investigations have fully justified these anticipations.

Excellent as we have found the text to be, it is difficult to speak with sufficiently high praise of the plates. To appreciate their value one should be familiar with Ctenophoræ, have watched them as the writer of this notice has done, day after day, and season after season, until their pictures can be called up with all the vividness of nature. A student familiar with Ctenophoræ, will recognize the truthfulness of these exquisite illustrations, in which every structural detail is sharp and firm, while nothing is lost in

delicacy of texture or grace of motion; and even one who has never seen a living Ctenophore, may study their structure in these wonderful plates, superior as they are to the very best figures thus far published. Dr. Chun is evidently as good an artist as he is a biologist, and we cannot close without congratulating him most heartily on the publication of this model monograph.

A. AG.

10. *The Spiral Character of Cœlenterate Development.*—Professor JOHN YOUNG, in the number of the Annals and Magazine of Natural History for March, 1880, argues from the order of development of the septa and tentacles that the radiate forms of Cœlenterates arises from the shortening and crowding together of the successive septa either side of a line of bilateral symmetry, by which an apparent radiation around the mouth is produced.

11. DR. ELLIOTT COUES' *Third Installment of American Ornithological Bibliography*, making Art. xxvi and pages 521 to 1066 of vol. v of the Bulletin of the U. S. Geological and Geographical Survey of the Territories, F. V. Hayden, U. S. Geologist-in-charge. Department of the Interior. Washington, September 30, 1880.—This bibliography, of over 500 closely printed pages, with the two preceding installments, "represent a nearly complete bibliography of Ornithology so far as America is concerned."

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Some incidental results from a series of analyses of air, made at Hudson, Ohio;* by EDWARD W. MORLEY.—The samples were taken daily, and at a regular hour. They were analyzed in duplicate. The greatest difference between the results of analyses of the same sample was ·016 per cent. The probable error of a single determination was less than ·003 per cent.

(1) The mean propertion of oxygen to the sum of oxygen and nitrogen for the first half of the year 1880 is as follows: January 20, ·951; February 20, ·935; March 20, ·949; April 20, ·950; May 20, ·949; June 20, 951; January to June 20, ·949.

(2) Uncertainties in callibration, errors of observation and manipulation, and variations in the quantity to be measured, make the probable error of the final mean less than ·002 per cent.

(3) Any given sample of air was as likely as not to differ from the mean of ·012 per cent.

(4) The probabilities are about ten to one that the differences between the means for any two months are within ·002 per cent of the truth.

(5) The largest proportion of nitrogen yet noticed was on December 29th, 1879, when three analyses of the same sample gave 21·045, 21·045, 21·044. The largest during the six months mentioned was March 9th: 21·001, 21·006.

(6) The lowest yet found was on February 26th, 1879, when, with another apparatus, there was found 20·45 and 20·50. The lowest during the six months was on February 14th, when one sample gave, 20·896 and 20·903; another sample gave 20·867.

2. *National Academy of Sciences.* — At the session of the National Academy in New York City, commencing November 17, the following papers were read:

On the basin of the Gulf of Mexico; J. E. HILGARD.

On the origin of the coral reefs of the Yucatan and Florida Banks; ALEXANDER AGASSIZ.

Observations on ice and icebergs in the polar regions; F. SCHWATKA.

The duration of the Arctic winter; F. SCHWATKA.

Mineralogical notes; BENJAMIN SILLIMAN.

The relationship of the Carboniferous Euphoberia to living and extinct Myriapods; SAMUEL H. SCUDDER.

On the ellipticity of the earth as deduced from pendulum experiments: C. S. PEIRCE.

An improvement in the Sprengel air-pump; O. N. ROOD.

The thermal balance; S. P. LANGLEY.

Measurement of radiant energy; S. P. LANGLEY.

Causes which determine the progressive movement of storms; ELIAS LOOMIS.

The antimony mines of Southern Utah; J. S. NEWBERRY.

The conglomerate ore deposits of the United States and Mexico; J. S. NEWBERRY.

On photographing the Nebula in Orion; HENRY DRAPER.

On condensers for currents of high potential; GEORGE F. BARKER.

Sigsbee's gravitating trap; ALEXANDER AGASSIZ.

Observations on ice and icebergs in the polar sea; Lieut. F. SCHWATKA, U. S. A.

The deposits of crystalline iron ores of Utah; J. S. NEWBERRY.

The origin of anthracite; T. STERRY HUNT.

On the star-list of Abul Hassan; C. H. F. PETERS.

Dimensions of the brain and spinal cord in some extinct reptiles; O. C. MARSH.

On the Mimoravidæ; E. D. COPE.

On the Miocene Canidæ; E. D. COPE.

On a new and general method in analysis; WOLCOTT GIBBS.

Note on the relations of the Oneonta and Montrose Sandstones with the sandstone of the Catskill Mountains; JAMES HALL.

3. *Annual Report of the Chief of Engineers to the Secretary of War, for the year* 1879. In three Parts, containing over 2400 pages 8vo.—Besides the special reports relating to forts, harbor and river surveys and improvements, and maps illustrating the same, there are the following: Report on the Contents of Troughton and Simms' Theodolite, No. 3, by Mr. R. S. WOODWARD, Assistant Engineer, (p. 1945); Report on the Errors of Certain Thermometers as to calibration, etc., by T. RUSSELL, (p. 1952; Report on Sand waves and Sediment observations in the Mississippi, by J. B. JOHNSON, (p. 1963); Annual Report of Capt. G. M. WHEELER, corps of Engineers, (pp. 1977–2313), and including the Reports of a geological party in Colorado and New Mexico from Spanish Peaks to the South, in 1878 and 1879, by Prof. J. J. STEVENSON, and an ornithological report on observations and collections made in portions of California, Nevada and Oregon, by Assistant H. W. HENSHAW.

The report of Captain Wheeler contains a long table of altitudes determined by the survey in Oregon, California, Nevada, New Mexico and Arizona.

The report includes also (pp. 2331 to 2343) a Chemical Report on the Pagosa Springs of Colorado by Dr. C. SMART, U. S. A., in whose waters sodium sulphate constitutes nearly two-thirds of

the material in solution (2·263 to 3·042 grains per liter), and the gases are carbonic acid and hydrogen sulphide; and pp. 2371–2395 a report on the Mammals and Birds of the general region of the Big Horn River and Mountains of Montana Territory, by C. E. McChesney, Asst. Surgeon, U. S. A.

4. *Report on the Meteorology of Tokio, for the year* 1879; by Prof. T. C. MENDENHALL.—This report forms Part I of vol. iii of the Memoirs of the Science Department of the University of Tokio. It contains the usual meteorological observations, and its notable feature is the free use of graphical representation of most of the results. Its forty-one pages of letter-press, including tables, are accompanied by *twenty-seven* pages of charts showing curves of barometer and thermometer, prevailing winds, rain-fall, etc. It is published by the University and is handsomely printed at the Government Printing Office. C. G. R.

5. *United States Commission of Fish and Fisheries, Part VI; Report of the Commissioner,* Dr. SPENCER F. BAIRD, *for the year* 1878. lxiv and 988 pp. 8vo. Washington. 1880.—The prominent subjects of this large volume are the history and statistics of food-fishes of different coasts, rivers, lakes, etc.; their decrease and the modes of preventing it; their propagation in the waters of the United States; the quality of fishes, their value, products, economical uses; the planting of American waters with ova from foreign countries and the reverse. What has been done in these directions, or is doing, together with a statement of the objects of the Fish Commission and of the assistance it has received from the departments of the Government, is briefly brought out in an Introductory Chapter of lxiv pages; and then follows the appendix, of 974 pages, which consists of papers giving full details and descriptions on these and other topics. Among these papers there are the following in descriptive Natural History: On the marine Isopoda of New England and adjacent waters (some of which are parasitic on fishes), by OSCAR HARGER, illustrated by 13 plates; on the Pycnogonida of the same region, by E. B. WILSON, with 7 plates. Another of botanical interest, is, on the nature of the peculiar reddening of salted codfish during the summer season, by W. G. FARLOW, in which the author shows that the red color is owing to a very minute plant known to botanists by the name of *Clathrocystis roseo-persicina;* that this plant is abundant on the marshes in the vicinity of Gloucester, and in the buildings where the fish are cured; that it exists in the salt imported from Cadiz, which salt is therefore to be avoided in the cure of the cod; and that the Trepani salt is pure from it or nearly so. Mr. Farlow describes also another minute plant from the red codfish of Gloucester, which he names *Sarcina? Morrhuæ.*

The volume, like its predecessors, bears ample testimony to the great value of the work of the Fish Commission, and to the able supervision and judicious management of the Commissioner, Professor Baird.

6. *Röntgen's Principles of Thermodynamics, with special applications to hot-air, gas and steam engines.* Translated, revised and enlarged by A. JAY DUBOIS. New York, 1880. John Wiley & Sons. 8vo, pp. xviii and 641.—The aim of the author and of the translator has been to furnish a work for the engineering profession and technical schools suited to the needs of beginners by the mode of treatment, and yet sufficiently wide in its scope and practical in its applications. Besides the extensive additions made by the translator himself there are given as an introduction to the whole subject two lectures of Verdet. The extent of the work is greater than is needed in the class room in order to serve as a book of reference. H. A. N.

7. *The American Naturalist.* — The American Entomologist, hitherto edited by Mr. C. V. Riley, has been united with the Naturalist, and the latter will hereafter have the able assistance of Mr. Riley in the Entomological department.

8. *The Kansas City Review of Science and Industry*, edited by T. S. CASE, is a monthly "Record of progress in science, mechanic arts, and literature," and aims to be "an exponent of Western thought and a means of communication of Western discoveries and theories." The December number contains the proceedings of the Kansas Academy of Science, and, in a briefer form, those of the St. Louis Academy of Science. It is published at Kansas City, Missouri, in monthly numbers of 64 pages each, for $2.50 a year.

9. *Medals of the Royal Society.*—The Copley Medal has been given the present year to Prof. J. J. Sylvester (of the Johns Hopkins University); Royal Medals to Prof. Joseph Lister and Capt. Andrew Noble; the Rumford Medal to Dr. William Huggins; and the Davy Medal to Prof. Charles Friedel of Paris.

10. *A Physical Treatise on Electricity and Magnetism;* by J. E. H. GORDON, B.A. In ten volumes. New York, 1880. (D. Appleton & Co.).—A notice of this work will appear in another number.

OBITUARY.

Sir BENJAMIN C. BRODIE, Bart., F.R.S., late Professor of Chemistry in the University of Oxford, died at Torquay on the 24th of November, in his sixty-fourth year.

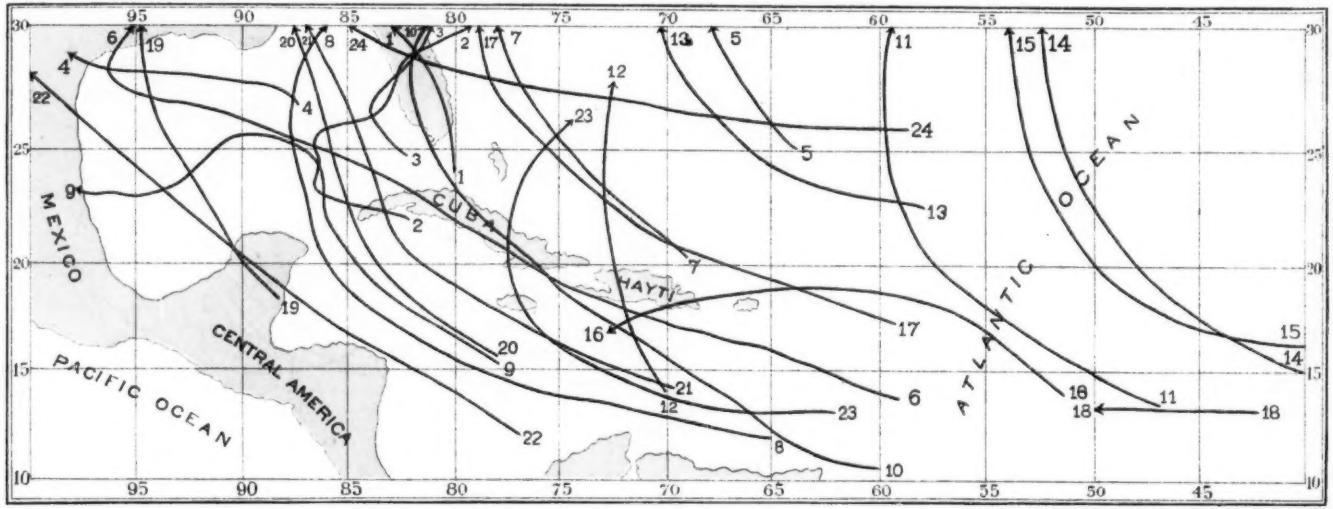
J. CHARLES ALMEIDA, the founder of the Société Française de Physique, and its Secretary, the author of a Traité de Physique, and formerly Professor of Physics in the Lyceum of Henry IV, died in November last.

MICHEL CHASLES, the eminent French mathematician, died, on the 18th of November, at his home in Chartres. He was born November 15, 1793.

TRACKS OF AMERICAN STORMS ADVANCING WESTERLY.

Am. J. Sci., Vol. XX, Art. 1, 1881.

PLATE I.



TRACKS OF AMERICAN STORMS ADVANCING SOUTHEASTERLY.

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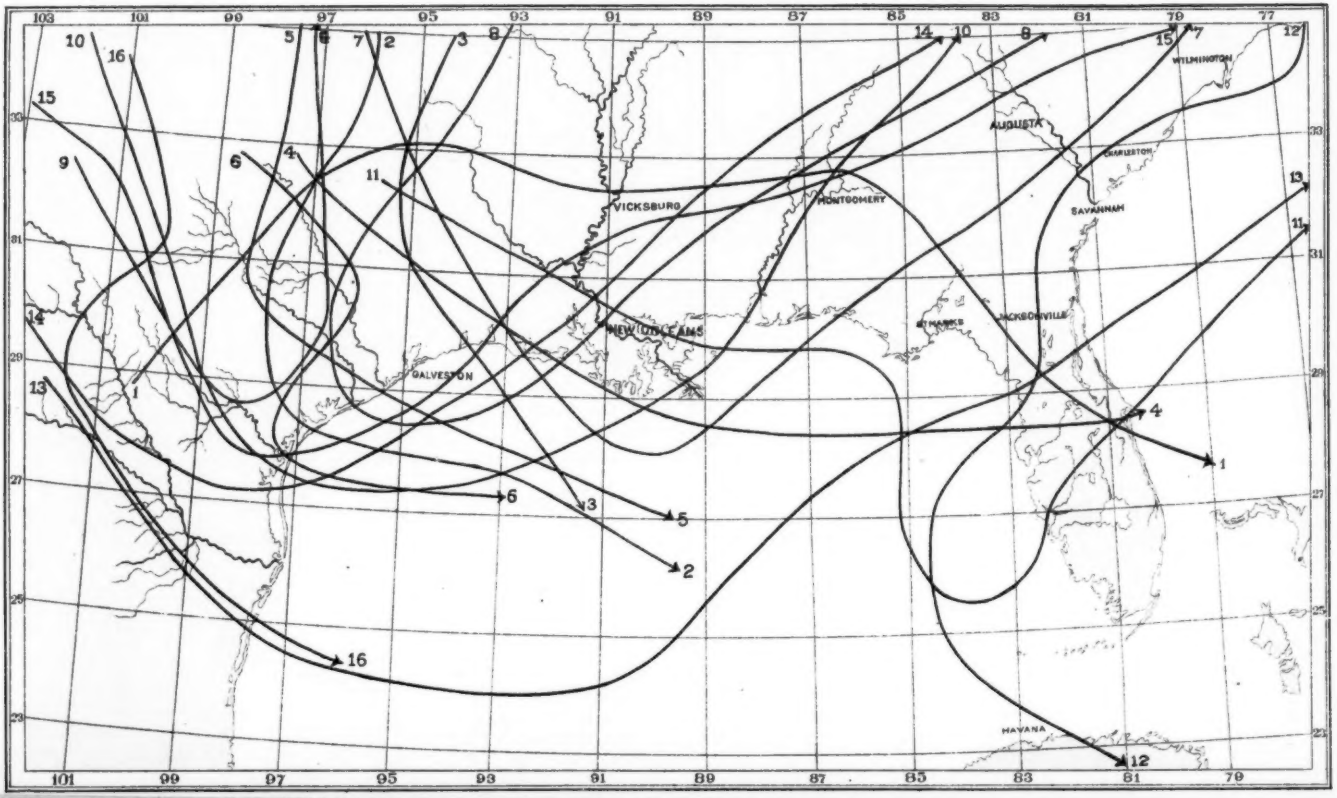
Am. J. Sci. Vol. XX, Art. 1. 1881.

PLATE II.

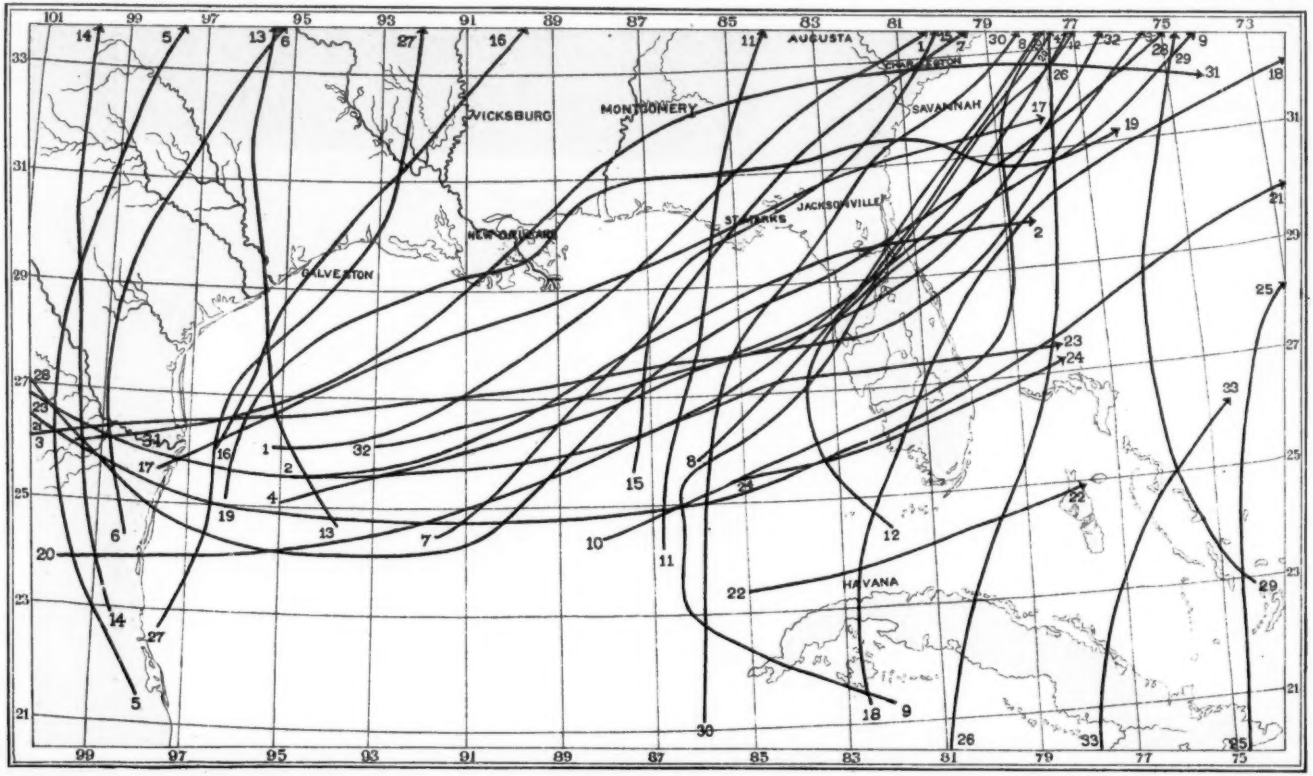


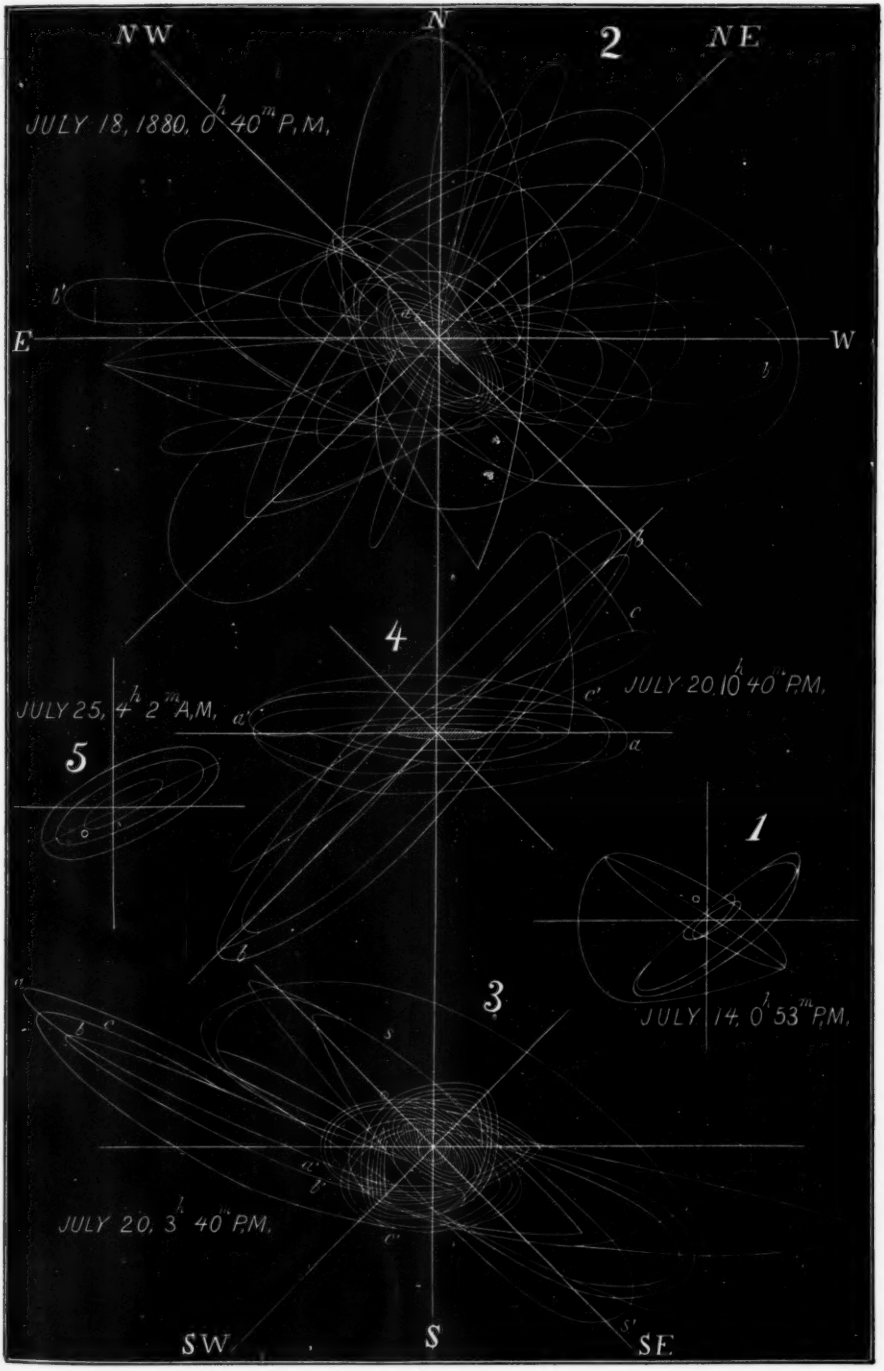
TRACKS OF AMERICAN STORMS ADVANCING NORTHEASTERLY.

TRACKS OF AMERICAN STORMS ADVANCING NORTHEASTERLY.

Am. J. Sci. Vol. XX., Art. 1. 1881.

PLATE III.

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